Road Models in Adams/Tire

Using the 2D Road Model

This section of the help provides detailed technical reference material for using Adams/Tire to define roads along which to maneuver a vehicle. It assumes that you know how to run Adams/Car, Adams/Solver, Adams/View, or Adams/Chassis. It also assumes that you have a moderate level of tire-modeling proficiency.

The 2D Road model lets you model two-dimensional road excitations, including a flat road. Learn about:

- 2D Road Types
- Examples of 2D Roads
- 2D Road Model Parameters

2D Road Types

The available road types are:

- DRUM - Tire test drum (requires a zero-speed-capable tire model).
- FLAT - Flat road.
- PLANK - Single plank perpendicular, or in oblique direction relative to x-axis, with or without bevel edges.
- POLY_LINE - Piece-wise linear description of the road profile. The profiles for the left and right track are independent.
- POT_HOLE- Single pothole of rectangular shape.
- RAMP - Single ramp, either rising or falling.
- ROOF - Single roof-shaped, triangular obstacle.
- SINE - Sine waves with constant wave length.
- SINE_SWEEP - Sine waves with decreasing wave lengths.
- STOCHASTIC_UNEVEN - Synthetically generated irregular road profiles that match measured stochastic properties of typical roads. The profiles for left and right track are independent, or may have a certain correlation.

Examples of 2D Roads

Sample files for all the road types for Adams/Car are in the standard Adams/Car database:

install_dir/shared_car_database.cdb/roads.tbl/

Sample files for all the road types for Adams/Tire are in:

install_dir/solver/atire/

Sample files for all the road types for Adams/Chassis are in:

install_dir/achassis/examples/rdf/

Note that you must select a specific contact method, such as point-follower or equivalent plane, to define how the roads will interact with the tires. Not all combinations of road, tire, and contact methods are permitted. Allowable combinations are explained in Tire Models help under the description of the specific tire model.

2D Road Model Parameters

The [PARAMETERS] block must contain the following data, some of which are independent of the type of road.

Learn about parameters:

- Independent of Road Type
- Drum
- Flat
- Plank
- Polyline
- Pothole
- Ramp
- Roof
- Sine
- Sweep
- Stochastic Uneven

Parameters Independent of Road Type

The following parameters are required regardless of the road type.

[PARAMETERS] Independent of Road Type

The parameter:	Indicates:
offset	A constant shift of the road height values. For a flat road and offset = 0, the road height is zero.

The parameter:	Indicates:
rotation_angle_xy_plane	Rotation angle of the xy-plane about the road z-axis. In Adams/Car, vehicles start running along the negative x-axis by default. It also might be convenient to use positive x-values in the .rdf. In that case, choose rotation_angle_xy_plane = 180 (deg).
mu	Road friction correction factor (not the friction value itself), to be multiplied with the respective rubber friction values of the tire model. Default setting: mu = 1.0.

Parameters for Road Type of Drum

If ROAD_TYPE = drum, then define the following parameters:

[PARAMETERS] for Road Type of Drum

The parameter:	Indicates:
diameter	Diameter of the tire test drum. When the diameter is < 0, the road model simulates the outer drum. With positive rolling speed, the inner drum will rotate clockwise and the outer drum counter-clockwise.
v	Rolling speed of drum surface (be sure to keep vehicle at speed zero, otherwise, the wheels move away from the drum). Drum center is located at x = 0.
number_cleats	Number of extra cleats on drum (number_cleats = 0 allowed).
cleat_height	Height of extra cleats.
cleat_starting_angle	Drum angle coordinate of first cleat.
cleat_length	Length of cleat, measured in circumferential direction of drum. Example of specifying cleat_length.
cleat_bevel_edge_length	Length of bevel edge of cleat, measured in circumferential direction of drum. Bevel edge has 45° slope. Example of specifying cleat_bevel_edge_length.
acceleration_time	Optional time span at the beginning of the simulation, during which the drum is accelerated to a nominal rolling speed.

Parameters for Road Type of Flat

If ROAD_TYPE = flat, then no further parameters are required.

Parameters for Road Type of Plank

If ROAD_TYPE = plank, then define the following parameters:

[PARAMETERS] for Road Type of Plank

The parameter:	Indicates:
height	Height of plank.
start	Start of plank (travel distance).
length	Length of plank, measured along x-axis.
bevel_edge_length	Length of bevel edge, measured along x-axis. Bevel edge has 45° slope. When bevel_edge_length < 0, rounded corners instead of bevel edges are used. In this case, radius of the corner is |bevel_edge_length|.
direction	Direction of plank relative to y-axis. If the plank is placed crosswise, direction = 0. If the plank is along the x-axis, direction = 90.

Parameters for Road Type of Polyline

If ROAD_TYPE = poly_line, then the [PARAMETERS] block must have a (XZ_DATA) subblock. The subblock consists of three columns of numerical data:

- Column one is a set of x-values in ascending order.
- Columns two and three are sets of respective z-values for left and right track.

The following is an example of the full [PARAMETERS] Body for a road type of polyline:

```
$----------------------------PARAMETERS

[PARAMETERS]

OFFSET = 0

ROTATION_ANGLE_XY_PLANE = 180

$
(XZ_DATA)
0 0 0

1000 100 50
2000 -1000 100

3000 -100 100

3001 50 0

4000 -100 100
```

The XZ_DATA subblock can be extremely large. In this case, only the portion that is needed at the moment is loaded. To facilitate efficient reloading while simulation is running, do not use any comment lines in a subblock that contains more than 2000 lines.

Parameters for Road Type of Pothole

If ROAD_TYPE = pot_hole, then the parameters are:

[PARAMETERS] Data for Road Type of Pothole

The parameter:	Indicates:
depth	Depth of pothole.
start	Start of pothole (travel distance).
length	Length of pothole.

Parameters for Road Type of Ramp

If ROAD_TYPE = ramp, then the parameters are:

[PARAMETERS] Data for Road Type of Ramp

The parameter:	Indicates:
height	Height of ramp.
start	Start of ramp (travel distance).
slope	Slope of ramp. 1 means 45°.

Parameters for Road Type of Roof

If ROAD_TYPE = roof, then the parameters are:

[PARAMETERS] Data for Road Type of Roof

The parameter:	Indicates:
height	Height of roof (triangle-shaped obstacle).
start	Start of roof (travel distance).
length	Length of roof, measured along x-axis.

Parameters for Road Type of Sine

If ROAD_TYPE = sine, then the parameters are:

[PARAMETERS] Data for Road Type of Sine

The parameter:	Indicates:
amplitude	Amplitude of sine wave (*a*).
wave_length	Wave length of sine wave (λ_e).
start	Start of sine waves (travel distance) (s_s).

The road height, z, is given by:

$$z(s) = a \cdot sin\left(\frac{2\pi}{\lambda}(s - s_s)\right)$$

Parameters for Road Type of Stochastic Uneven

A stochastic uneven road profile both for left and right wheels is generated, with properties very close to measured road profiles.

In a first step, discrete white noise signals are formed on the basis of nearly uniformly distributed random numbers. Two of these numbers are assigned to every 10 mm of travel path. The distribution of these random numbers is approximated by summing several equally distributed random numbers, taking advantage of the ‘law of large numbers’ of mathematical statistics.

Next, these values are integrated with respect to travel distance, using a simple first order time-discrete integration filter. The independent variable of that filter is not time, but travel path. That is why the filter cutoff frequency is controlled by a path constant instead of a time constant. The filter process results in two approximate realizations of white velocity noise; that is, two signals, the derivatives of which are close to white noise. Signals with that property are known as road profiles with waviness 2. Several investigations in the past showed that the waviness derived from measured road spectral densities ranges from about 1.8 to 2.2.

The last step is to linearly combine the two realizations of the above process: $z_1(s), z_2(s)$, resulting in the left and right profile $z_l(s), z_r(s)$. This is done such that the two signals are completely independent if $corr_{rl} = 0.0$, and identical if $corr_{rl} = 1.0$:

$$z_l(s) = z_1(s) + \frac{corr_{rl}}{2}(z_2(s) - z_1(s))$$

$$z_r(s) = z_2(s) - \left(\frac{corr_{rl}}{2}\right)(z_2(s) - z_1(s))$$

If ROAD_TYPE = stochastic_uneven, then the parameters are:

[PARAMETERS] for Road Type of Stochastic Uneven

The parameter:	Indicates:
intensity	Variable to control intensity of white velocity noise, which approximates measured spectra of road profiles fairly well.
path_constant	Variable to control high-pass integration filter.
correlation_rl	Variable to control correlation between left and right track: • If 0, no correlation. • If 1, complete correlation (that is, left track = right track). Can be any value between 0 and 1.
start	Start of unevenness (travel distance).

Parameters for Road Type of Sweep

If ROAD_TYPE = sine_sweep, then the parameters are:

[PARAMETERS] Data for Road Type of Sine Sweep

The parameter:	Indicates:
start	Start of swept sine wave (travel distance) (s_s).
end	End of swept sine wave (travel distance) (s_e).
amplitude_at_start	Amplitude of swept sine wave at start travel distance (a_s).
amplitude_at_end	Amplitude of swept sine wave at end travel distance (a_e).
wave_length_at_start	Wave length of swept sine wave a start travel distance (λ_s).

The parameter:	Indicates:
wave_length_at_end	Wave length of swept sine wave at end travel distance. Must be less than or equal to wave_length_at_start (λ_e).

The parameter:	Indicates:
sweep_type	• sweep_type = 0: frequency increases linearly with respect to travel distance. • sweep_type = 1: wave length decreases by a constant factor per cycle. Depending on the value of sweep_type, the road height is given by the following functions, where: $f_s = \frac{1}{\lambda_s}$ and $f_e = \frac{1}{\lambda_e}$ • **Linear sweep:** (sweep_type = 0) The frequency increases linearly with respect to travel distance. The road height value $z(s)$ as function of travel distance s is calculated as follows: $z(s) = \left(a_s + \frac{(a_e - a_s)(s - s_s)}{(s_e - s_s)}\right) \cdot sin\left(2\pi \cdot \left(f_s + \frac{(f_e - f_s)(s - s_s)}{2(s_e - s_s)}\right) \cdot (s - s_s)\right)$ Note the factor 2 in the denominator is not an error. The actual frequency (= derivative of the sine function argument with respect to travel path, divided by 2π; this is not equal to that factor that is multiplied by $2\pi(s - s_s)$ in the sine function) is given by the following: $f(s) = f_s + \frac{(f_e - f_s)(s - s_s)}{s_e - s_s}$ • **Logarithmic sweep:** (sweep_type = 1) with every cycle, the wave length decreases by a constant factor. The road height value is calculated as follows: $z(s) = \left(a_s + \frac{a_e - a_s}{s_e - s_s}(s - s_s)\right) \cdot sin\left(2\pi f_s s_\infty ln\left(\frac{s_\infty}{s_\infty + s_s - s}\right)\right)$ where: $s_\infty = \frac{f_e}{f_e - f_s}(s_e - s_s)$ s_∞ is the travel path where theoretically an infinitely high frequency was reached, measured relative to sweep start s_s. The actual frequency is given by: $f(s) = \frac{s_\infty}{s_\infty + s_s - s} f_s$

Adams/3D Spline Road Model

Learn how to use the Adams/3D Spline Road model to define a road:

- About Adams/3D Spline Road
- Adams/3D Spline Road Perturbation Types
- Adams/3D Spline Road Perturbation Keywords
- Using Adams/3D Spline Road
- About the Adams/3D Spline Road Property File

About Adams/3D Spline Road

Adams/3D Spline Road lets you define an arbitrary three-dimensional smooth road surface, such as parking structures, racetracks, and so on. A smooth road is a road surface with a curvature, which is less than the curvature of the tire. In addition, Adams/3D Spline Road lets you model three-dimensional road obstacles, which are placed on top of the underlying smooth road surface.

The road centerline, width, bank angle, and left and right friction levels define the road surface completely. The road data is stored in an XML file, which you can create and modify using the Road Builder (Learn more about Using the Road Builder). The legacy TeimOrbit road definition file (.rdf) is still supported, and can be translated to XML using the Road Builder. For a description of the information contained in the .rdf file, see About the Adams/3D Spline Road Property File.

By specifying the coordinates of the road centerline, you can construct any line in three-dimensional space. Adams/3D Spline Road assumes a flat cross-section for which the bank angle and width can be specified for each data point. In addition, you can specify friction levels for left and right road sides.

Using Adams/3D Spline Road

You can reference the Adams/3D Spline Road just as you do any other .rdf by selecting your desired road from an appropriate database. In addition, both Adams/Car and Adams/Chassis have a Adams/3D Spline Road event, called 3D Spline Road. Graphics for the road are automatically generated for animation purposes.

In the current version of Adams/3D Spline Road, both Adams/Car and Adams/Chassis offer multiple methods to access the Adams/3D Spline Road capabilities:

- When running any full vehicle simulation you may use an Adams/3D Spline Road data file for the road.
- When using with Driving Machine, you may also use a road data file as you would a driver control data (.dcd) file to specify the vehicle path. The Driving Machine will then drive the vehicle along the centerline of the road.
- When using with Adams/SmartDriver, you can use the road data file to replace the driver road data (.drd) file. In this case, the vehicle will use the x, y, and z road centerline to define the vehicle path.

Examples of event (.xml) file for use with Driving Machine and Adams/SmartDriver are shown next:

For Driving Machine:

```
<DcfMini name="3D_SMOOTH_ROAD" active="true"
         userDefined="false" smoothingTime="0.1"
         activeFlag="true" abortTime="1"
         stepSize="0.01" hMax="0"
      >
        <DcfDemand name="steering" active="true"
           userDefined="false"
           demandType="steering"
           actuatorType="rotation"
           controlMethod="machine"
           controlMode="absolute"
           controlType="constant"
           constantValue="0" initialValue="0" finalValue="0"
           startTime="0" duration="0" rampValue="0"
           maximumValue="0" cycleLength="0" amplitude="0"
           initialFrequency="0" frequencyRate="0"
           maximumFrequency="0" functionString="0"
        >
       …
        <DcfMachine name="machine" active="true"
           userDefined="false"
           steerControl="file"

dcdSteerFile="mdids://acar_shared/roads.tbl/3d_road_smooth_ramp.xml"
             steerRadius="0"
             steerEntry="0"
             turnDirection="right"
             pathPositioning="default"
           speedControl="lon_accel"
             velocity="0" acceleration="0" jerk="0"
             startTime="0.1"
           samplePeriod="0.01"
         >
```

For Adams/SmartDriver:

```
DcfMini name="3D_SMOOTH_ROAD" active="true"
         userDefined="false" smoothingTime="0.1"
         activeFlag="true" abortTime="1"
         stepSize="0.01" hMax="0"
      >
        <DcfDemand name="steering" active="true"
           userDefined="false"
           demandType="steering"
           actuatorType="rotation"
           controlMethod="SmartDriver"
```

```
            controlMode="absolute"
            controlType="constant"
            constantValue="0" initialValue="0" finalValue="0"
            startTime="0" duration="0" rampValue="0"
            maximumValue="0" cycleLength="0" amplitude="0"
            initialFrequency="0" frequencyRate="0"
            maximumFrequency="0" functionString="0"
         >
        …
         <DcfSmartDriver name="smartdriver" active="true"
            userDefined="false" task="vehicle_limits"

courseFile="mdids://acar_shared/roads.tbl/3d_road_smooth_ramp.xml"
            max_driving_accel="70" max_braking_accel="70"
            max_lh_turn_accel="70" max_rh_turn_accel="70"
            samplePeriod="0.01"
         />
```

Adams/3D Spline Road Perturbation Types

The available road perturbations are:

- CROWN - Road crown along the road centerline.
- CURB - Curb at left, right, or both sides of the road.
- PLANK - Single plank with beveled edges or rounded corners.
- POLYLINE - Cubic spline description of the road profile for left and right wheel track.
- POTHOLE - Pothole of rectangular shape.
- RAMP - Ramp, either rising or falling.
- ROOF - Roof-shaped, triangular obstacle.
- ROUGHNESS - Generated irregular road profiles with stochastic properties similar to measured roads.
- SINE - Sine wave with constant amplitude and wavelength.
- SWEEP - Sine wave with variable amplitude and wavelength.
- GRID - Regular Grid obstacle, the road height is defined by a matrix of road height points at equal distance

Note that a specific contact method has to be selected, which defines how Adams/3D Spline Road interacts with the tires. Not all combinations of road, tire, and contact methods are permitted. For more information, see the topics under Tire Model in the Table of Contents.

Be aware that Adams/3D Spline Road perturbations can generally have small wavelength content. Therefore, the combination of tire and contact methods should be able to handle this type of excitation.

Any number of perturbations can be defined. If an overlap exists between the perturbations, then Adams/3D Spline Road superpositions the perturbations.

Adams/3D Spline Road Perturbation Keywords

The following sections explain the keywords for each perturbation type and those independent of the perturbation type:

- Independent of Perturbation Type
- Coordinate System
- Crown Perturbation Type
- Curb Perturbation Type
- Plank Perturbation Type
- Polyline Perturbation Type
- Pothole Perturbation Type
- Ramp Perturbation Type
- Roof Perturbation Type
- Roughness Perturbation Type
- Sine Perturbation Type
- Sweep Perturbation Type
- Grid Perturbation Type

Keywords Independent of Perturbation Type

You must specify the following data in the .rdf file, independent of the type of perturbation.

Keywords Independent of Perturbation Type

Keyword:	Description:
COORDINATE_SYSTEM	The type of coordinate system: • local for a local perturbation-bound coordinate system. • distance if the perturbation is defined along the length of the road.
START	The start position of the perturbation. • '0.0 0.0 0.0' for a local coordinate system. • '0.0' for a distance-defined perturbation.
STOP	The stop position of the perturbation. • '1.0 0.0 0.0' for a local coordinate system. • '1.0' for a distance-defined perturbation.
LENGTH	The length of the perturbation. LENGTH is used in defining the local coordinate system.

Keyword:	Description:
WIDTH	The width of the obstacle. The obstacle width can be specified independently of the road width.
FRICTION	The friction coefficient of the obstacle.
ROAD_TYPE	The perturbation type.

Coordinate System Keywords

Depending on the COORDINATE_SYSTEM keyword you selected as shown in Keywords Independent of Perturbation Type, you can use two types of coordinate systems:

- **Local coordinate system** - The START and STOP keywords define the local coordinate system, while the interconnecting line and the LENGTH keyword provide the direction of the perturbation. Adams/3D Spline Road projects the road profile height in the local coordinate system onto the smooth road surface.
- **Distance coordinate system** - The START and STOP positions are expressed in distance along the road centerline or chord length. The direction and length are, therefore, defined implicitly.

The following combinations of coordinate system and perturbation types are valid:

Valid Combinations of Perturbation Type and Coordinate System

Perturbation type:	Coordinate system:	
	Local:	Distance:
CROWN		X
CURB		X
PLANK	X	
POLYLINE		X
POTHOLE	X	
RAMP	X	
ROOF	X	
ROUGHNESS		X
SINE	X	
SWEEP	X	
GRID	X	

Keywords for Crown Perturbation Type

If ROAD_TYPE = 'CROWN', then you must specify the keyword DATA_BLOCK = 'CROWN DATA', with the name of the subblock (CROWN_DATA). The subblock consists of three columns of numerical data:

- The first column is a set of distance-values in ascending order.
- The second column contains the height of the crown.
- The third column contains the crown coefficient.

The road profile height z is a function of width-coordinates ρ, obstacle width w, height z_0, and crown coefficient c_r:

$$z(\rho) = z_0 - 4\frac{c_r}{w}\rho^2$$

See Illustration of Crown.

Keywords for Curb Perturbation Type

If ROAD_TYPE = 'CURB', then you must specify the following keywords. Illustration of Curb Keywords.

Keywords for Curb Perturbation Type

Keyword:	Description:
HEIGHT	Height of the curb(s).
ROUND_OFF	Round-off radius of the top of the curb.
TOP_WIDTH	The width of the top of the curb.
EDGE_WIDTH	The width of the edge of the curb.
SIDE	The side of the road where the curb is positioned: • **LEFT** • **RIGHT** • **BOTH**

Keywords for Plank Perturbation Type

If ROAD_TYPE = 'PLANK', then you must specify the following keywords.

Illustration of keywords for:

- Edged Plank

- Rounded Plank

Keywords for Plank Perturbation Type

Keyword:	Description:
HEIGHT	Height of the plank.
BEVEL_EDGE_LENGTH	Length of the beveled edge. A beveled edge has a 45º slope. When BEVEL_EDGE_LENGTH < 0, 3D Spline Road uses rounded corners instead of beveled edges. In this case, the radius of the corner is |BEVEL_EDGE_LENGTH|.

Keywords for Polyline Perturbation Type

If ROAD_TYPE = 'POLYLINE', then you must specify the keyword DATA_BLOCK = 'XZ_DATA', with the name of the subblock (XZ_DATA). The subblock consists of three columns of numerical data:

- The first column is a set of distance-values in ascending order.
- The second and third columns contain the road profile height of the left and right tracks, respectively.

Keywords for Pothole Perturbation Type

If ROAD_TYPE = 'POTHOLE', then you must specify the 'DEPTH' keyword, which specifies the depth of the pothole.

Illustration of Pothole keywords.

Keywords for Ramp Perturbation Type

If ROAD_TYPE = 'RAMP', then you must specify the following keywords. Illustration of Ramp keywords.

Keywords for Ramps Perturbation Type

Keyword:	Description:
HEIGHT	Height of the ramp.
SLOPE	Slope of ramp. 1 corresponds to 45º.

Keywords for Roof Perturbation Type

If ROAD_TYPE = 'ROOF', then you must specify the following keywords. Illustration of Roof keywords.

Keywords for Roof Perturbation Type

Keyword:	Description:
HEIGHT	Height of the roof.
LENGTH	Length of the base of the triangular roof.

Keywords for Roughness Perturbation Type

The roughness perturbation type uses a mathematical model developed by Sayers (1.). The model is empirical; it is based on the observed characteristics of many measured profiles of roads of various types. The model provides the synthesis of profiles for both the left and right wheel tracks.

If ROAD_TYPE = 'ROUGHNESS', then you must provide the following keywords:

Keywords for Roughness Perturbation Type

Keyword:	Description:
GE	Elevation PSD parameter.
GS	Velocity PSD parameter.
GA	Acceleration PSD parameter.
SAMPLE_INTERVAL	The distance between the road profile data points.
CORRELATION_BASE LENGTH	Correlation base length for filtering (recommended value = 5.0 m).
SEED	Seed for random numbers. • If seed is negative, the computer's clock is used as a seed. An infinite number of profiles can be generated to match the same set of Sayers-model parameters. • If seed is greater than zero, the value of the seed is used as the seed to the random-number generator. This is a means of generating reproducible profiles with the Sayers model.

References:

1. Sayers, M.W., "Dynamic Terrain Inputs to Predict Structural Integrity of Ground Vehicles." UMTRI Report No. UMTRI-88-16, April 1988, 114 pp.

Keywords for Sine Perturbation Type

If ROAD_TYPE = 'SINE', then you must provide the following keywords. Illustration of Sine keywords.

Keywords for Sine Perturbation Type

Keyword:	Description:
AMPLITUDE	Amplitude of the sine wave (a).
WAVE_LENGTH	Wave length of the sine wave (l).

The road profile height z, is given by:

$$z(s) = a \cdot sin\left(\frac{2\pi}{\lambda} \cdot s\right)$$

Keywords for Sweep Perturbation Type

If ROAD_TYPE = 'SWEEP', then you must provide the following keywords. Illustration of Sweep Keywords.

Keywords for Sweep Perturbation Type

Keyword:	Description:
AMPLITUDE_AT_START	Amplitude of the sine wave at start (as a_s).
AMPLITUDE_AT_END	Amplitude of the sine wave at end (ae a_e).
WAVE_LENGTH_AT_START	Wave length of the sine wave at start (ls l_s).

Keyword:	Description:
WAVE_LENGTH_AT_END	Wave length of the sine wave at end (le l_e).
SWEEP_TYPE	• SWEEP_TYPE = 0, then frequency changes linearly. • SWEEP_TYPE = 1, then frequency changes logarithmically. Depending on the value of SWEEP_TYPE, the road profile height is given by the following functions: • **Linear sweep** - The frequency changes linearly with distance s. The road profile height z is given by: $z(s) = \left[a_s + \frac{(a_e - a_s)(s - s_s)}{s_e - s_s}\right] \cdot sin\left[2\pi \cdot f_s \cdot s_\infty \cdot ln\left(\frac{s_\infty}{s_\infty + s_s - s}\right)\right.$ • **Logarithmic sweep** - With every cycle, the wavelength decreases by a constant factor. The road profile is given by: $z(s) = \left[a_s + \frac{(a_e - a_s)(s - s_s)}{s_e - s_s}\right] \cdot sin\left[2\pi \cdot \left(f_s + \frac{(f_e - f_s)(s - s_s)}{2(s_e - s_s)}\right)\right.$ where: $s_\infty = \frac{f_e}{f_e - f_s}(s_e - s_s)$ s¥ is the distance at which, theoretically, an infinitely high frequency is reached, with respect to the start ss.

Keywords for Grid Perturbation Type

If ROAD_TYPE = 'GRID', then you must specify the keyword DATA_BLOCK = 'GRID DATA', with the name of the sub block (GRID_DATA). The sub block should contain the road height data points as function of the x- and y- position. The local start coordinates will correspond to the first row and the center column will run along the line from START to STOP. In the example below, the z_{13} corresponds to the local START coordinates. Column 3 will be along the START to STOP direction.

```
z11 z12 z13 z14 z15
z21 z22 z23 z24 z25
z31 z32 z33 z34 z35
z41 z42 z43 z44 z45
z51 z52 z53 z54 z55
z61 z62 z63 z64 z65
z71 z72 z73 z74 z75
```

```
z81 z82 z83 z84 z85
z91 z92 z93 z94 z95
```

The lateral distance between two points in a row is determined by the WIDTH of the obstacle and the number of points in a row:

distance_y = WIDTH / (number of points in a row -1)

Similar, the longitudinal distance between two points in a column is determined by the LENGTH of the obstacle and the number of points in a column:

distance_x = LENGTH / (number of points in a column -1)

3D Spline Road will calculate the road height using cubic splines through the road height data points. See Illustration of Grid keywords.

About the Adams/3D Spline Road Property File

The following sections explain the data blocks in the Adams/3D Spline Road property file (*.rdf*). The last section contains a sample *.rdf*.

- File Details
- Units Details
- Model Details
- Global Parameters
- Data Points Information
- Sample Road Data File

File Details

The first block of data, [MDI_HEADER], describes the TeimOrbit file:

```
[MDI_HEADER]
FILE_TYPE    = 'rdf'
FILE_VERSION = 5.00
FILE_FORMAT  = 'ASCII'
{COMMENTS}
'User entered comments go here'
```

MDI_HEADER Keywords

The keywords:	Contains:
FILE_TYPE	The file type.
FILE_VERSION	Version of file; to be changed when modifications to this file are made.

The keywords:	Contains:
FILE_FORMAT	The format of the data; for TeimOrbit, this is always ASCII.
{COMMENTS} 'User entered comments go here'	Descriptive comments about the file, such as what road this represents, when the data was acquired, and so on.

Units Details

The [UNITS] blocks defines the units for the road:

```
[UNITS]

 LENGTH  = 'meter'
 FORCE   = 'newton'
 ANGLE   = 'radians'
 MASS    = 'kg'
 TIME    = 'sec'
```

[UNITS] Keywords

The keywords:	Specifies:
LENGTH	Unit of length.
FORCE	Unit of force.
ANGLE	Angle in radians or degrees.
MASS	Unit of mass.
TIME	Unit of time.

Model Details

The [MODEL] block defines the road model and version:

```
[MODEL]
 METHOD  = '3D_SPLINE'
 VERSION = 1.00
```

[MODEL] Keywords

The keyword:	Determines:
METHOD	Road contact algorithm that Adams/Tire uses. You must set method='3D_SPLINE' to instruct Adams/Tire to use the Adams/3D Spline Road spline algorithm.
VERSION	Version of 3D_SPLINE algorithm being used; currently, 1.00.

Global Parameters

The [GLOBAL_PARAMETERS]block defines parameters applying to the entire road.

```
[GLOBAL_PARAMETERS]

 CLOSED_ROAD        = 'NO'
 SEARCH_ALGORITHM   = 'FAST'
 ROAD_VERTICAL      = '0.0 0.0 1.0'
 FORWARD_DIR        = 'NORMAL'
 MU_LEFT            = 0.5
 MU_RIGHT           = 0.6
 WIDTH              = 5.000
 BANK               = 0.0
```

[GLOBAL_PARAMETERS) Keywords

The keyword:	Specifies:
CLOSED_ROAD	Whether the road is closed or open. If the road is not structured to be closed (the beginning and end of the road are not facing each other) and you select the closed option, Adams/Tire creates a deformed road. • **YES** - The road is closed. • **NO** - The road is open.
SEARCH_ALGORITHM	The type of algorithm to be used to determine the contact location. For smooth roads, we recommend Fast algorithm. • **FAST** - Specifies Fast algorithm.With Fast algorithm, caching is used if the input point is within 1×10^{-6} [m] distance from the previous input point. • **SLOW** - Specifies Slow algorithm. With Slow algorithm, no caching is used and the greatest accuracy is achieved.
ROAD_VERTICAL	Vector specifying the z-axis of the user-coordinate system with respect to ISO-coordinate system. This option allows you to specify the road data points in your preferred reference frame. During simulation, Adams/Tire converts all the data points to the ISO-reference frame based on the ROAD_VERTICAL values: '0.0 0.0 1.0' - The z-axis of user-reference frame with respect to ISO reference frame.
FORWARD_DIR	Forward direction of the road: • **NORMAL** - Vehicle travels along the specification of road data point. • **INVERT** - Vehicle travels in a direction opposite to that of specified road data points.

The keyword:	Specifies:
MU_LEFT	Road friction value on the left side of the road with respect to the centerline of the road. Specifying road friction under [GLOBAL_PARAMETERS] overwrites any specification of road friction values in the [DATA_POINTS] block. See Data Points Information.
MU_RIGHT	Road friction value on the right side of the road with respect to the centerline of the road. Specifying road friction under [GLOBAL_PARAMETERS] overwrites any specification of road friction values in the [DATA_POINTS] block. See Data Points Information.
WIDTH	Width of the road. If you specify WIDTH, it takes precedence over the WIDTH value specified in the [DATA_POINTS] block. Even if this parameter is set, you must specify the WIDTH parameter in [DATA_POINTS]. If this parameter is not required, then you can omit it from the road data file (.rdf). See Data Points Information.
BANK	Slope angle of the road around its centerline in each data point. Zero bank means a horizontal width line. A positive value specifies a slope along a clockwise direction in ISO-reference frame. If you specify this dimension, then it takes precedence over the BANK value specified in the [DATA_POINTS] block. Even if you set this dimension, you must specify a BANK value. If this dimension is not required, then you can omit it from the .rdf file. See Data Points Information.

Data Points Information

The [DATA_POINTS] block contains the road information in a tabular form. The following information needs to be supplied for each entry.

```
[DATA_POINTS]
 {    X       Y       Z      WIDTH    BANK    MU_LEFT    MU_RIGHT
OBSTACLES }
```

[DATA_POINTS] Keywords

The keyword:	Specifies:
X	X coordinate of sampled road data point.
Y	Y coordinate of sampled road data point.
Z	Z coordinate of sampled road data point.
WIDTH	Width of road at the sampled point.
BANK	Angle of road at the sampled point; positive value specifies a slope along a clockwise direction in ISO-reference frame.

The keyword:	Specifies:
MU_LEFT	Road friction on the left side of road with respect to the centerline of the road at the sampled point.
MU_RIGHT	Road friction on the right side of road with respect to the centerline of the road at the sampled point.
OBSTACLES	The name of block that contains the perturbation information. This entry is optional.

Sample Road Data File

```
$----------------------------------------------------MDI_HEADER
[MDI_HEADER]
  FILE_TYPE         =  'rdf'
  FILE_VERSION      =  5.00
  FILE_FORMAT       =  'ASCII'
  (COMMENTS)
  {comment_string}
  'Example of 3d Smooth road'
 $-------------------------------------------------------------UNITS
[UNITS]
  LENGTH              = 'meter'
  FORCE               = 'newton'
  ANGLE               = 'radians'
  MASS                = 'kg'
  TIME                = 'sec'
 $----------------------------------------------------DEFINITION
 [MODEL]
  METHOD              = '3D_SPLINE'
 $-------------------------------------------------ROAD_PARAMETERS
 [GLOBAL_PARAMETERS]
  CLOSED_ROAD         = 'NO'
  SEARCH_ALGORITHM    = 'FAST'
  ROAD_VERTICAL       = '0.0 0.0 1.0'
  FORWARD_DIR         =  'NORMAL'
  MU_LEFT             =  0.5
  MU_RIGHT            =  0.5
  WIDTH               =  5.000
  BANK                =  0.0

$-----------------------------------------------------DATA_POINTS
[DATA_POINTS]
{    X            Y           Z       WIDTH   BANK   MU_LEFT   MU_RIGHT
OBSTACLES }
12.50000E+00  4.60432E-15  0.00000E-00  7.000   0.000   0.900
0.900
10.50000E+00  4.60432E-15  0.00000E-00  7.000   0.000   0.900
0.900
5.50000E+00  4.60432E-15  0.00000E-00  7.000   0.000   0.900     0.900
CROWN
0.50000E+00  4.60432E-15  0.00000E-00  7.000   0.000   0.900     0.900
```

```
 1.53081E-18  1.42109E-17  0.00000E-00  7.000   0.000   0.900
0.900
-2.50000E+00  4.68958E-16  0.00000E-00  7.000   0.000   0.900
0.900
-5.00000E+00  9.37916E-16  0.00000E-00  7.000   0.000   0.900
0.900
-7.50000E+00  1.39266E-15  0.00000E-00  7.000   0.000   0.900
0.900
-1.00000E+01  1.84741E-15  0.00000E-00  7.000   0.000   0.900
0.900
-1.25000E+01  2.30216E-15  0.00000E-00  7.000   0.000   0.900
0.900
-1.50000E+01  2.77112E-15  0.00000E-00  7.000   0.000   0.900
0.900
-1.75000E+01  3.22586E-15  0.00000E-00  7.000   0.000   0.900
0.900
-2.00000E+01  3.69482E-15  0.00000E-00  7.000   0.000   0.900
0.900
$----------------------------------------------------END_DATA_POINTS
[CROWN]
COORDINATE_SYSTEM = 'distance'
START = 7
STOP = 16
WIDTH = 4
ROAD_TYPE = 'CROWN
DATA_BLOCK = 'CROWN_DATA'
FRICTION = 0.900


(CROWN_DATA)
{S HEIGHT CROWN}
7.00000E+00 0.00000E+00 0.00000E+00
8.00000E+00 1.25000E-02 3.12500E-03
9.00000E+00 5.00000E-02 1.25000E-02
1.00000E+01 8.75000E-02 2.18750E-02
1.10000E+01 1.00000E-01 2.50000E-02
1.20000E+01 1.00000E-01 2.50000E-02
1.30000E+01 1.00000E-01 2.50000E-02
1.40000E+01 1.00000E-01 2.50000E-02
1.50000E+01 1.00000E-01 2.50000E-02
1.60000E+01 1.00000E-01 2.50000E-02
```

Using the Road Builder

The Road Builder lets you create and edit 3D Spline Road property files in XML format. It is available in Adams/Car and Adams/Chassis.

The following sections explain more about the Road Builder:

- Conversion of TeimOrbit Format 3D Spline Road Property Files to XML Format
- Starting the Road Builder

- Creating Road Property Files
- Opening Road Property Files
- Changing Units
- Saving Changes
- Displaying Header Information and Adding Comments
- Setting Global Parameters
- Setting Soil Properties
- Defining Road Data Points
- Defining Obstacles
- Defining Analytical Road

Conversion of TeimOrbit Format 3D Spline Road Property Files to XML Format

The Road Builder does not use TeimOrbit property files. If you open a TeimOrbit 3D Spline Road property file in the Road Builder, it automatically converts it to XML format. This XML 3D Spline Road property file is stored in the working directory and loaded in the Road Builder.

Starting the Road Builder

To start the Road Builder in Adams/Car:

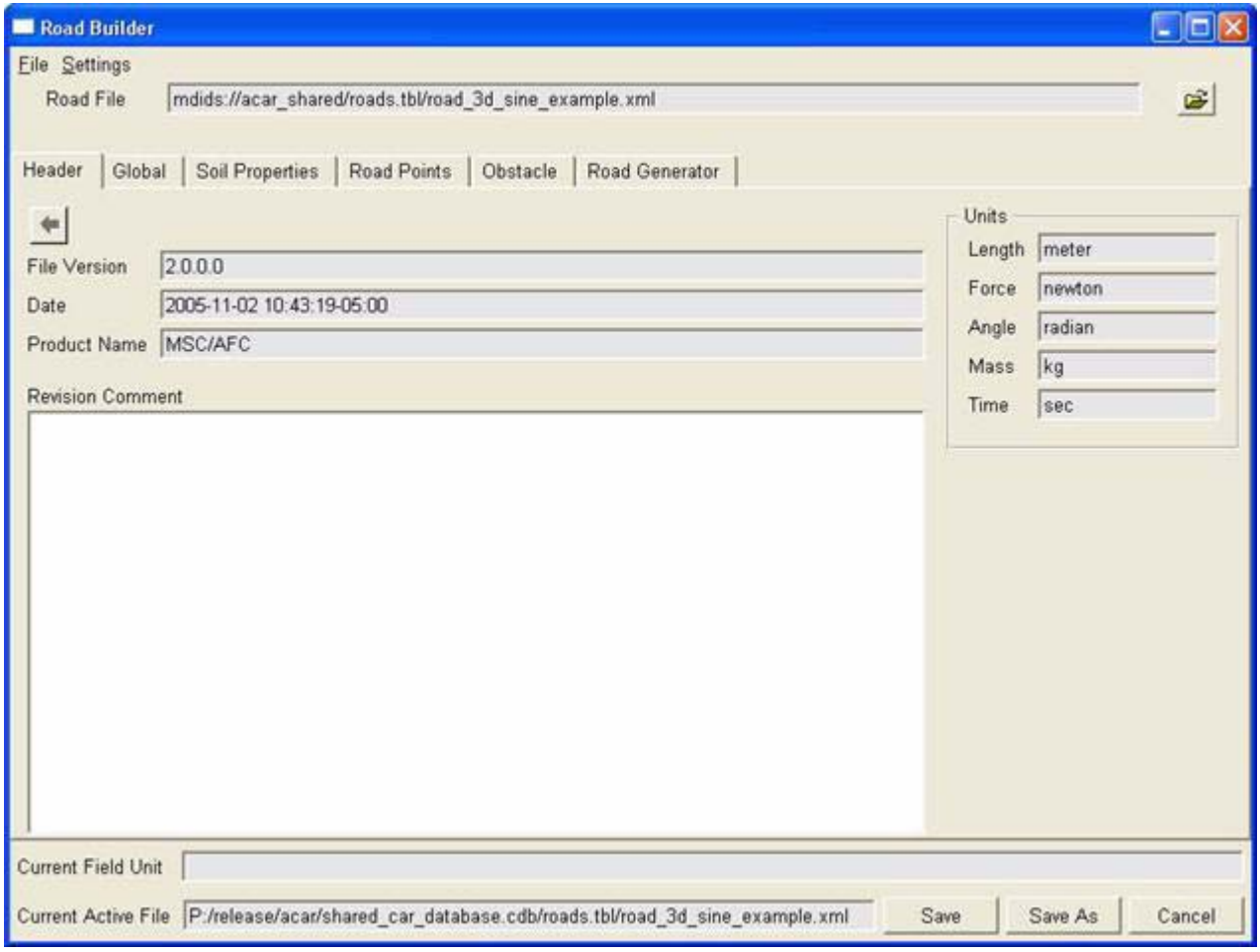
- From the **Simulate** menu, point to **Full-Vehicle Analysis**, and then select **Road Builder**.

To start the Road Builder in Adams/Chassis:

- In **Build** mode, from the **Utilities** menu, select **Road Builder**.

In both cases, the Road Builder starts with the road_3d_sine_example.xml example road property file loaded as shown in the figure below. The Road Builder consists of six tabs:

- **Header** - Displays header and units information and lets you enter comments. Learn more.
- **Global** - Sets parameters for the entire road. Learn more.
- **Soil Properties** - If road is used for the Soft Soil Tire model, the soil properties should be entered. Learn more.
- **Road Points** - Sets parameters that define the points in the road. Learn more.
- **Obstacle** - Defines obstacles in the road. Learn more.
- **Road Generator** - Allows the user to create/modify road data file using segments. Learn more.



Creating a 3D Spline Road Property File

To create a new 3D Spline Road property file:

- From the **File** menu, select **New**.

When you create a new 3D Spline Road property file, the default values of the road vertical are set to (0.0, 0.0, 1.0). Note that the road vertical is normalized at the Adams/Solver level.

Opening an Existing 3D Spline Road Property File

To edit an existing 3D Spline Road property file, do one of the following:

- From the **File** menu, select **Open**, and then browse for the desired file.

- To the right of the **Road File** text box, select the **Browse** button , and then browse for the desired file.

Changing Units

To change the units:

1. From the **Settings** menu, select **Units**.
2. Change the units, and then select **OK**.

Saving Changes

To save changes you make to the XML file:

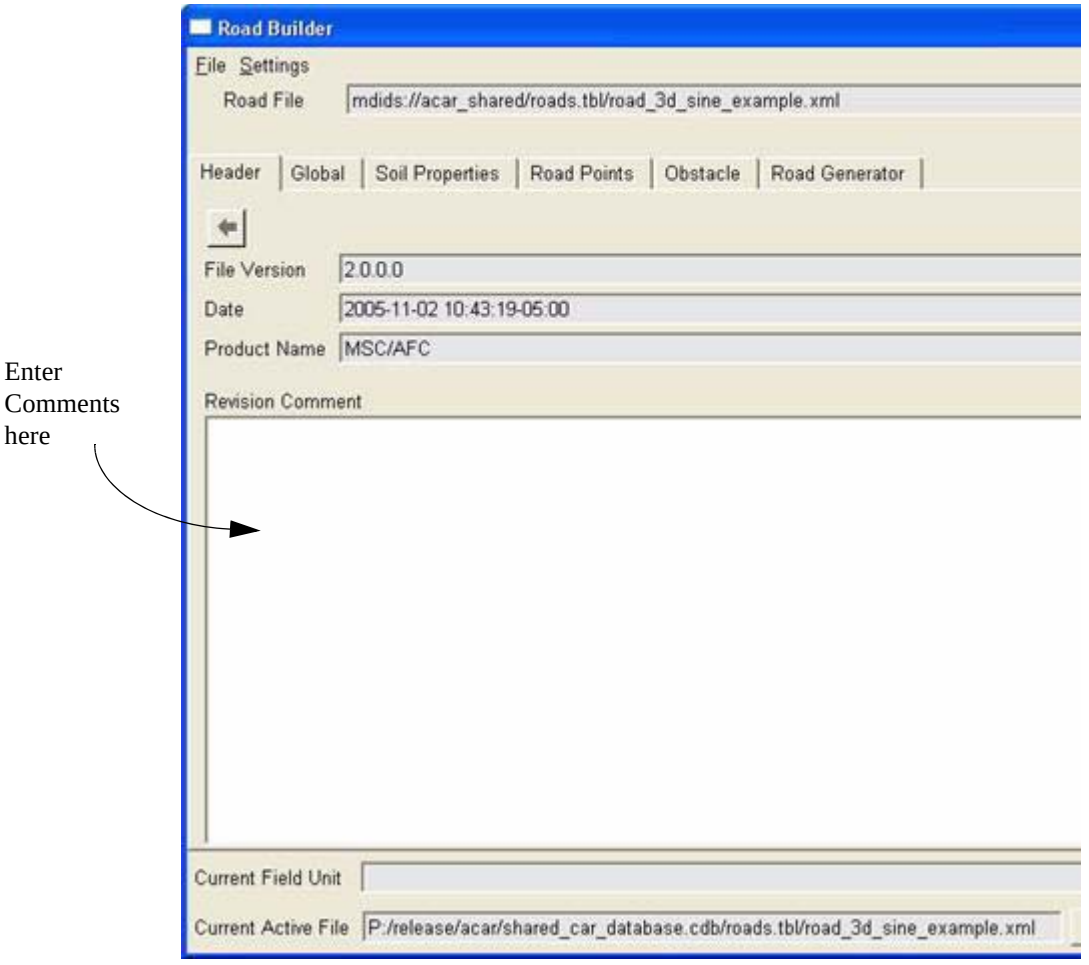
1. At the bottom of the Road Builder, select either **Save** or **Save As**.
2. If you selected **Save As**, enter the file name, and then select **OK**.

Displaying Header Information and Adding Comments

The Header tab shows information about the road file and the units of the 3D Spline Road object. You can add comments in the Revision Comment area, as shown in the figure below.

To display header information and add comments:

1. Select the **Header** tab.
2. View the information and in the **Revision Comment** area, enter any comments to help you manage the road property file.



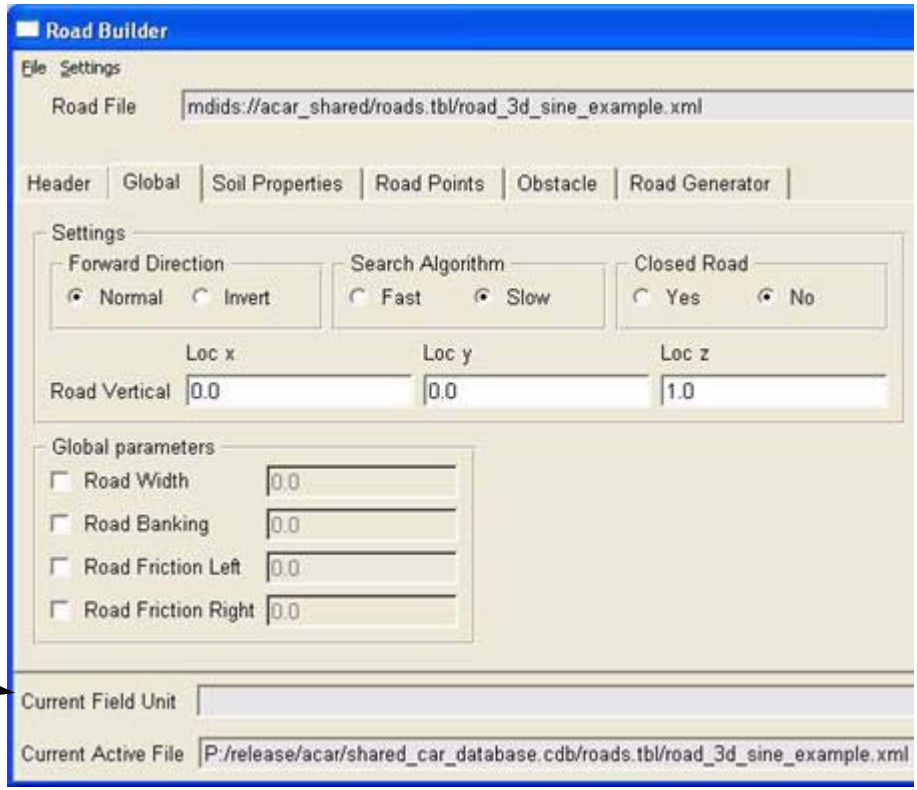
Setting Global Parameters

Parameters that apply to the entire road are defined in the Global Tab, shown below. Learn more about the global parameters.

To edit the parameters:

1. Select the **Global** tab.
2. Change the parameters as explained in global parameters.

Tip: To help you correctly enter values, the units for the current parameter appear in the **Current Field Unit** text box.

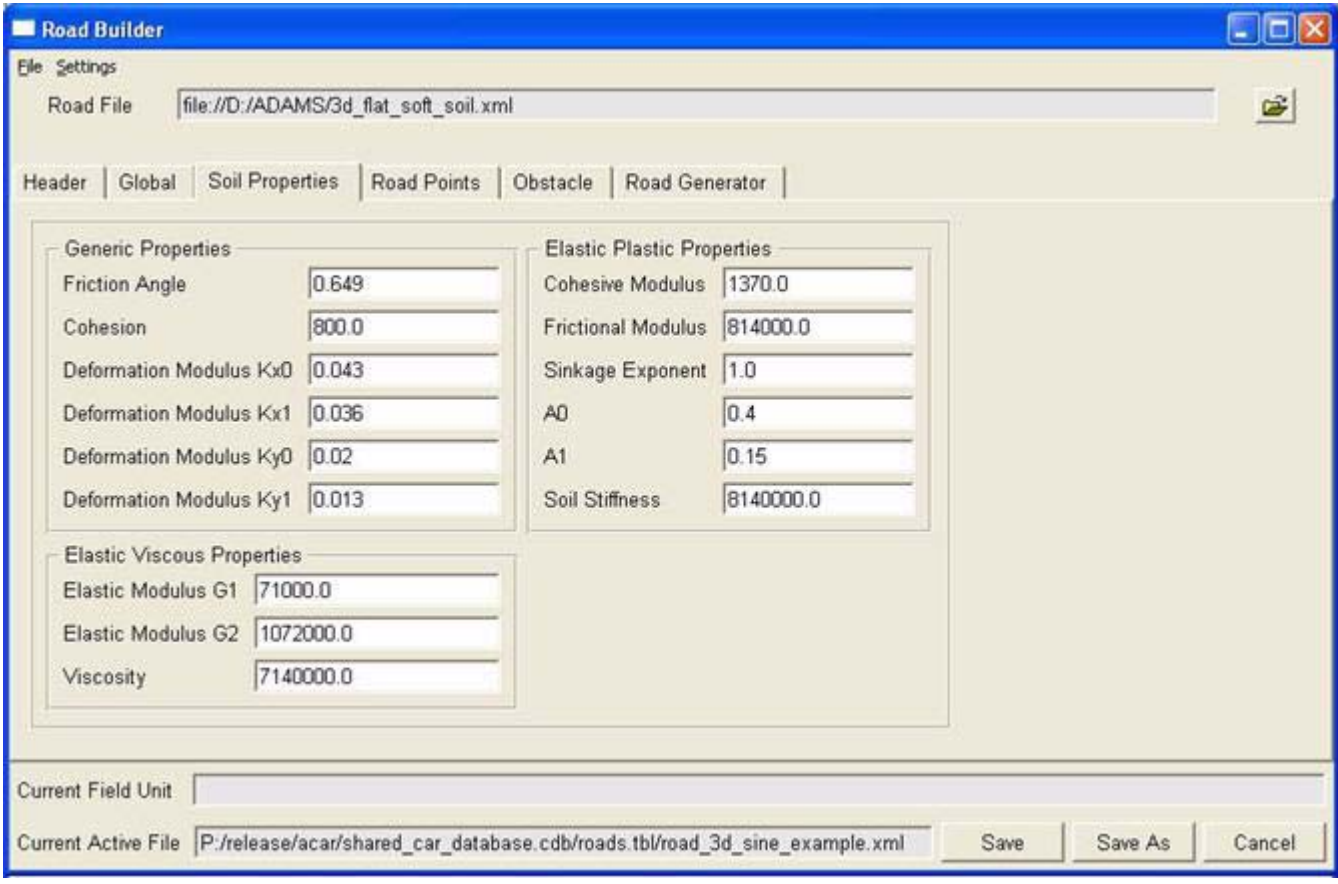


Displays units of currently selected parameter

Setting Soil Properties

In case that the road is used for the Soft Soil Tire model the soil properties should be entered. These properties are used by the Soft Soil Tire model only: when the Soil Properties are in the road data file, but another tire model is used, they are ignored.

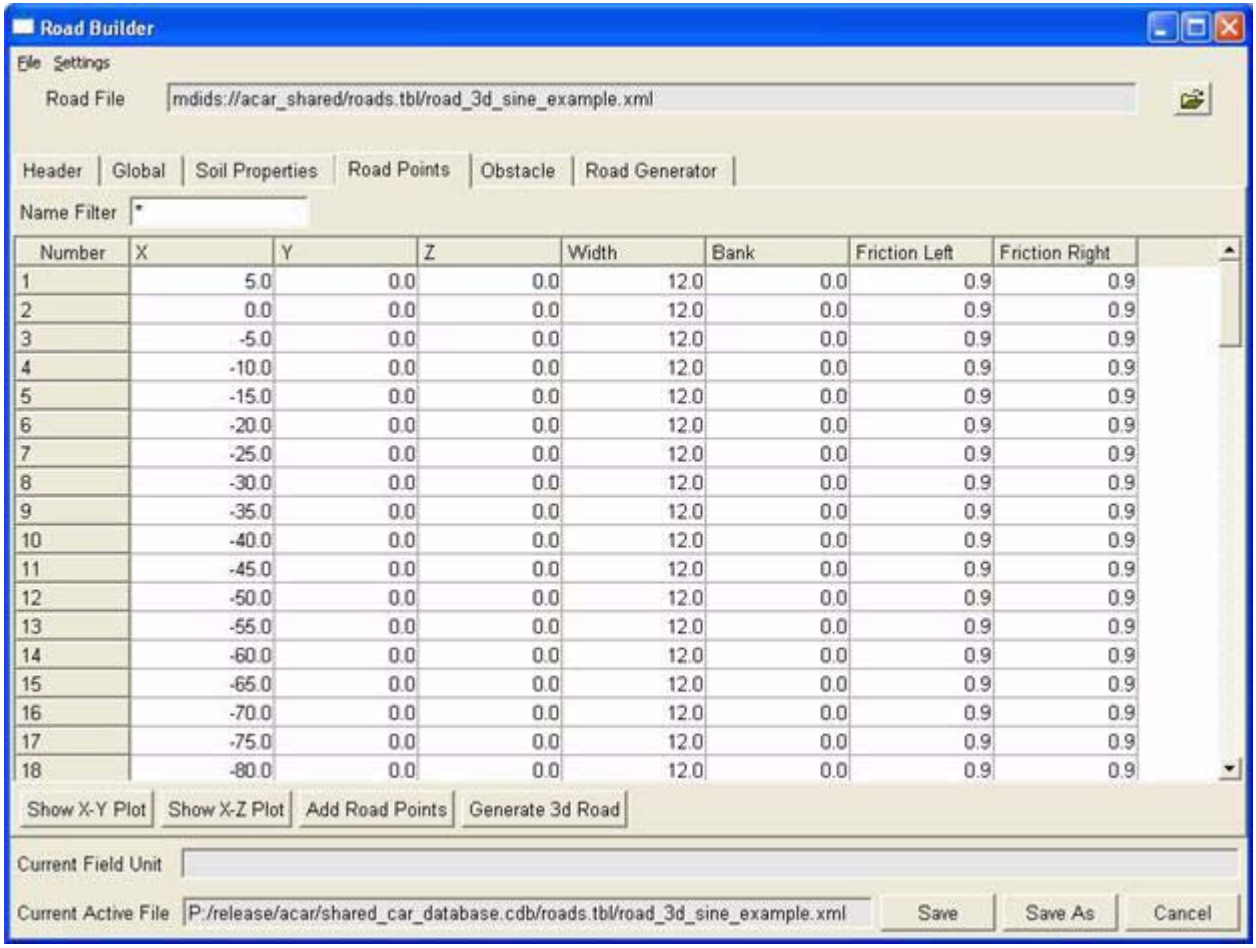
Note that the Soil Properties will be valid for the whole road area, no sections with specific other values can be defined.



Defining Road Data Points

The Road Points tab shows the Road Data Points table, as shown in the figure below. Learn about 3D Spline Road data points. Using the table, you can add and delete road data points and display the points as a plot so you can visualize the road and make changes to it.

- Working with Data Rows
- Plotting Road Data Points



Number	X	Y	Z	Width	Bank	Friction Left	Friction Right
1	5.0	0.0	0.0	12.0	0.0	0.9	0.9
2	0.0	0.0	0.0	12.0	0.0	0.9	0.9
3	-5.0	0.0	0.0	12.0	0.0	0.9	0.9
4	-10.0	0.0	0.0	12.0	0.0	0.9	0.9
5	-15.0	0.0	0.0	12.0	0.0	0.9	0.9
6	-20.0	0.0	0.0	12.0	0.0	0.9	0.9
7	-25.0	0.0	0.0	12.0	0.0	0.9	0.9
8	-30.0	0.0	0.0	12.0	0.0	0.9	0.9
9	-35.0	0.0	0.0	12.0	0.0	0.9	0.9
10	-40.0	0.0	0.0	12.0	0.0	0.9	0.9
11	-45.0	0.0	0.0	12.0	0.0	0.9	0.9
12	-50.0	0.0	0.0	12.0	0.0	0.9	0.9
13	-55.0	0.0	0.0	12.0	0.0	0.9	0.9
14	-60.0	0.0	0.0	12.0	0.0	0.9	0.9
15	-65.0	0.0	0.0	12.0	0.0	0.9	0.9
16	-70.0	0.0	0.0	12.0	0.0	0.9	0.9
17	-75.0	0.0	0.0	12.0	0.0	0.9	0.9
18	-80.0	0.0	0.0	12.0	0.0	0.9	0.9

Working with Data Rows

You can edit any of the data in the rows of the Road Data Points table and add or delete rows. The following provide you with the basics of enter data points in the table.

To edit the values in a row:

- Select the value you want to change, and then type a new value. Learn about the data point values.

To add rows to the Road Data Points table:

1. Select **Add Road Points**, located below the table.
2. Enter the number of data points you want to enter, and then select **OK**.

The Road Builder adds the rows to the end of the table.

To delete rows in the Road Data Point table:

- Select the row or rows you want to delete, right-click the column **Number**, and then select **Delete Row(s)**.

The Road Builder renumbers the rows of the table.

To add a single row to the end of the table:

- Right-click the column **Number**, and then select **Add Row**.

To insert a single row below a selected row:

- Right-click the row in the column below which you want to add a row, and then select **Insert Row**.

To copy and paste data in rows:

- Highlight the text you want to copy, and then select an copy **(CTRL + C)** data from a source and paste **(CTRL + V)** it in the road data points table.

Plotting Road Data Points

You can visualize the road data plots by plotting them as x-y (x values versus y values) or x-z plots (x values versus z values).

Note that if both the x-y plot and x-z plots are active, changes to road data points in one plot are not automatically updated in the other plot. Close and reopen the plot after updating the main road data points table.

Displays table of points, which can edit directly

To plot the road data points:

- Select **Show X-Y Plot** or **Show X-Z Plot** to create a plot of the road, as shown in the figure above for x-y values.

To fit the display of the plot into the plotting window, do one of the following:

- Select **Fit**.
- Right-click the plot, and then select **Fit**.

To view the data points in the plot:

- Right-click the plot, and then select **Show Symbols**.
- To view the data points as a curve:
- Right-click the plot, and then select **Show Curve**.

To zoom the display:

1. Select **Zoom**.
2. using the mouse, draw a box around the area of the plot you want to view.

To modify the road data points:

1. Right-click the plot, and then select **Show Symbols**.
2. Drag the points using the mouse. The new coordinates for the data points update in the table on the right.
3. Select **OK**. (The road data points are not updated in the main table until you select OK.)

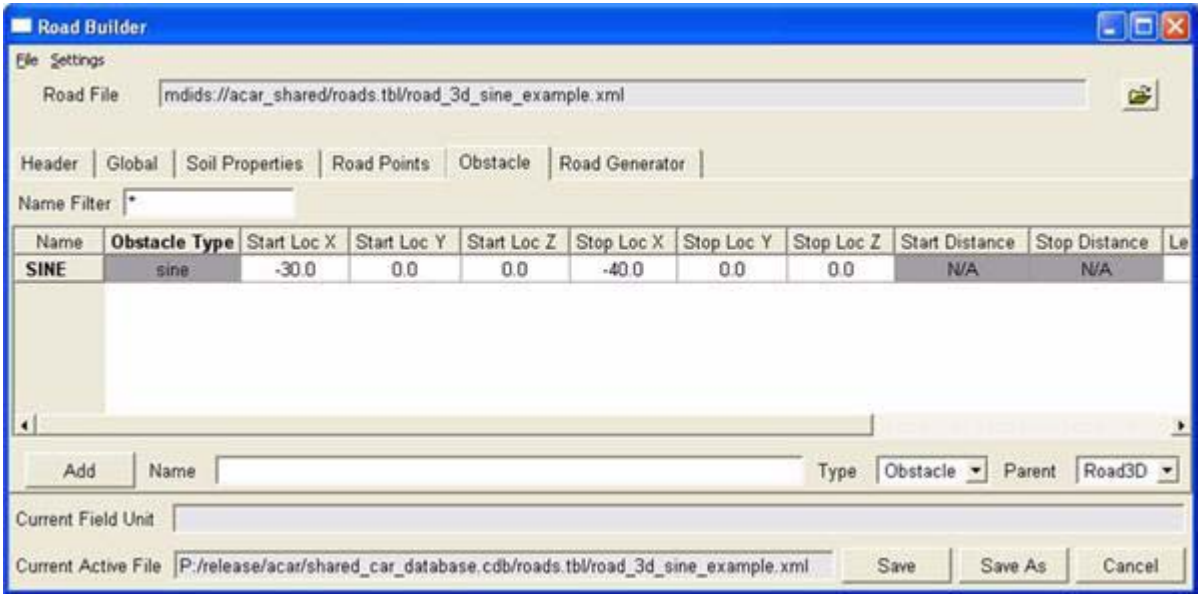
To exit the plot:

- In the upper right corner, select the **X**.

Defining Obstacles

The Obstacle tab shows the 3D Spline Road obstacles (also called road perturbations). If there is more than one road obstacle, the Obstacle tab displays the Obstacle table, as shown in the figure below. If there is only one road obstacle, the Obstacle tab shows the Obstacle Property Editor. You can only create a new obstacle in the Obstacle table.

For each obstacle, all parameters are stored in the XML format 3D Spline Road property file. This will make it easy to change obstacle type for a particular obstacle if data already exists.



Adding, Deleting, and Renaming Obstacles

To create a new road obstacle in the Obstacle table:

1. In the **Name** text box, enter the name of the obstacle.

2. Select **Add**.
3. Enter the values for the obstacle as explained in Adams/3D Spline Road Perturbation Keywords

To rename an obstacle:

- Right-click the obstacle name in the table, select **Rename Obstacle**, and then enter a new name.

To delete an obstacle:

- Right-click the obstacle name in the table, select **Delete Obstacle**.

Using the Obstacle Property Editor

The Obstacle Property Editor, shown in the figure below, shows the common and obstacle-specific parameters. The obstacle-specific parameters portion of the dialog box only shows those parameters that belong to the selected obstacle type.

Note that you cannot change the coordinate system in the Common Obstacle portion as the obstacle type determines whether Local or Distance should be used.

You manage the data in the tables for the Polyline and Crown obstacle types in the same way you do road data points. For more information on adding, deleting, and copying/pasting of data, see Defining Road Data Points.

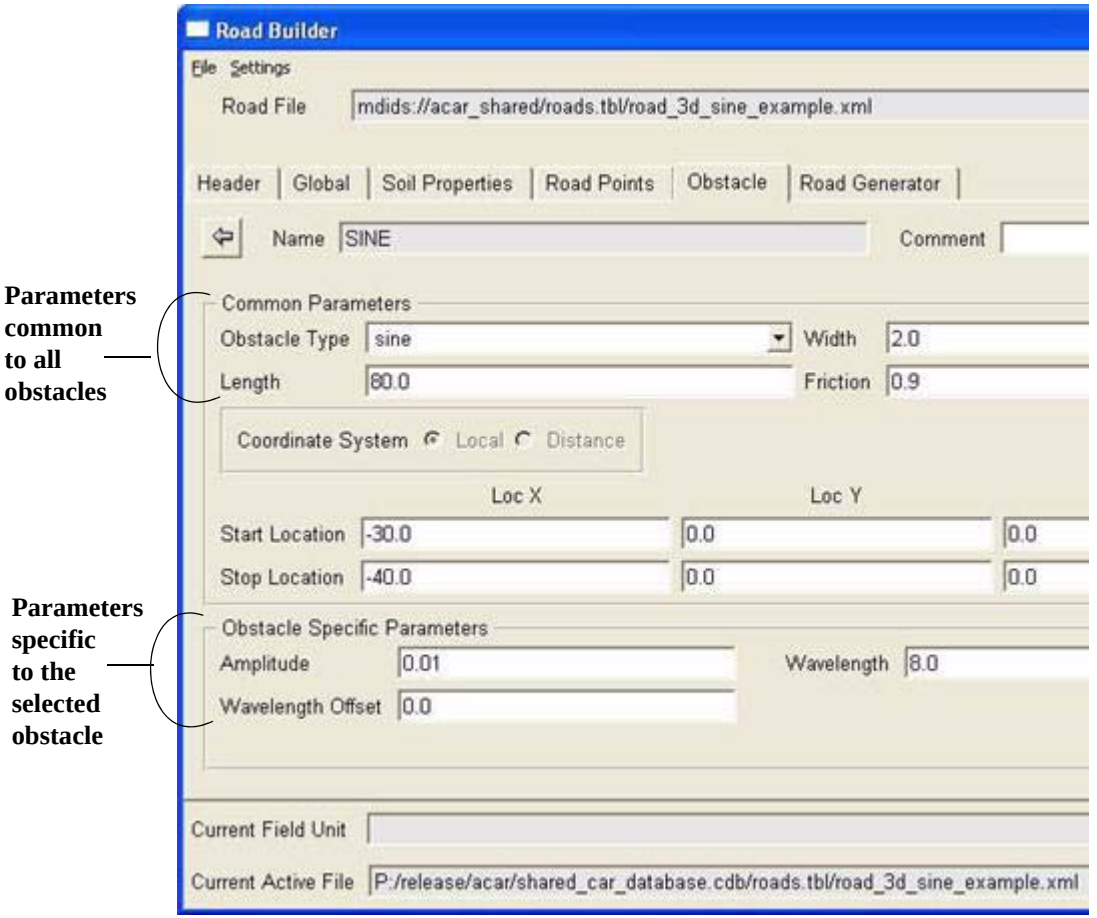
To display the Obstacle Property Editor, do one of the following:

- Right-click the obstacle name in the Obstacle table, and then select **Modify with PropertyEditor**.
- Double-click the obstacle name in the obstacle table.

To return to the Obstacle table:

- Click the arrow at the top left side.
- To edit the values:
- Change the values as explained in Adams/3D Spline Road Perturbation Keywords.

Tip: To help you correctly enter values, the units for the current parameter appear in the **Current Field Unit** text box.

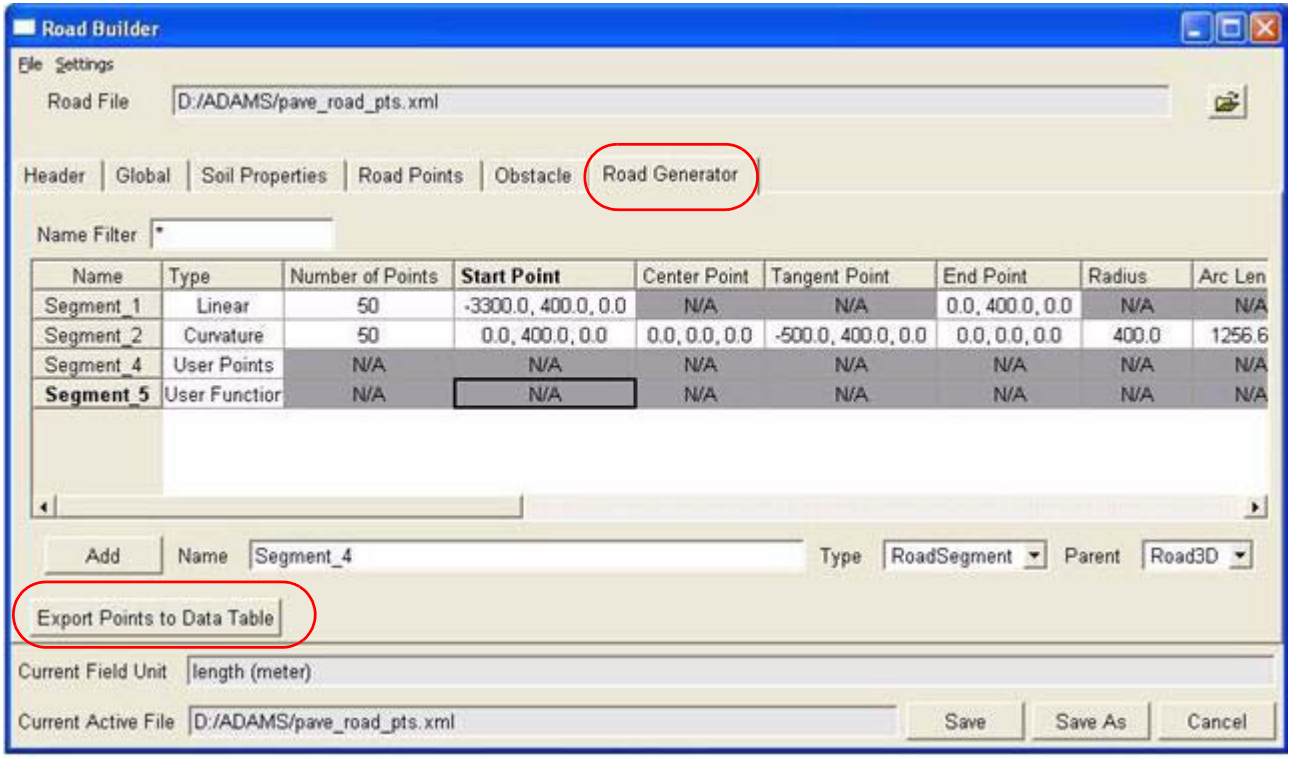


Defining Analytical Road

Following example illustrates how to create/modify a road model analytically from scratch in Adams/Road Builder. Road data can be created with multiple segments, each segment representing predefined formulations like Linear, Curvature, and Transition Curve or through User Defined Functions and User Defined Points.

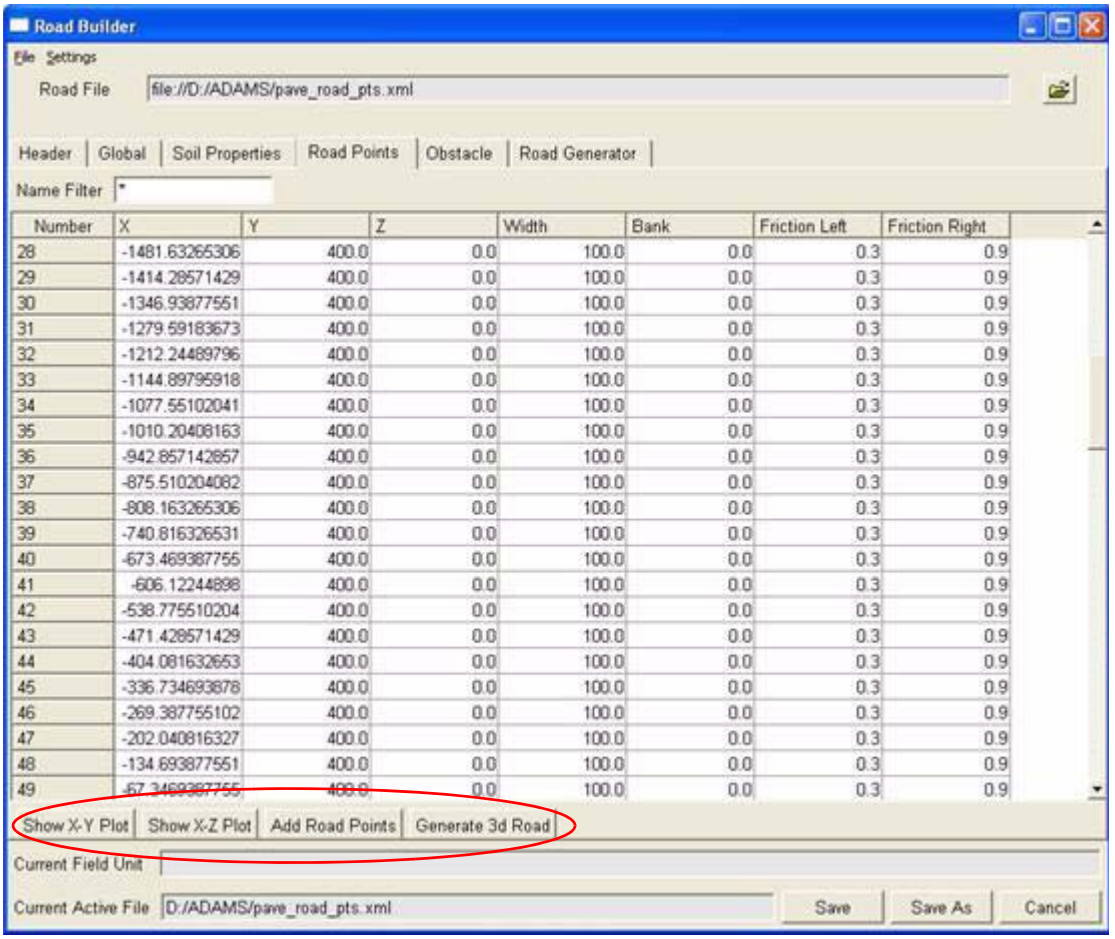
Steps to Create a Road Data File:

New tab **Road Generator** is added to the Road Builder GUI. This tab allows the user to create/modify road data file using segments.



To create a new segment, enter segment name in the **Name** field and click **Add** button. Segment name should be unique. To make it easier for the user to create road profile, some basic functions were created. User can use these functions by giving appropriate values.

To see the road points click on **Export points to Data Table** this will calculate the road points according to the segment function and export them to the **Road Points** tab in the GUI.



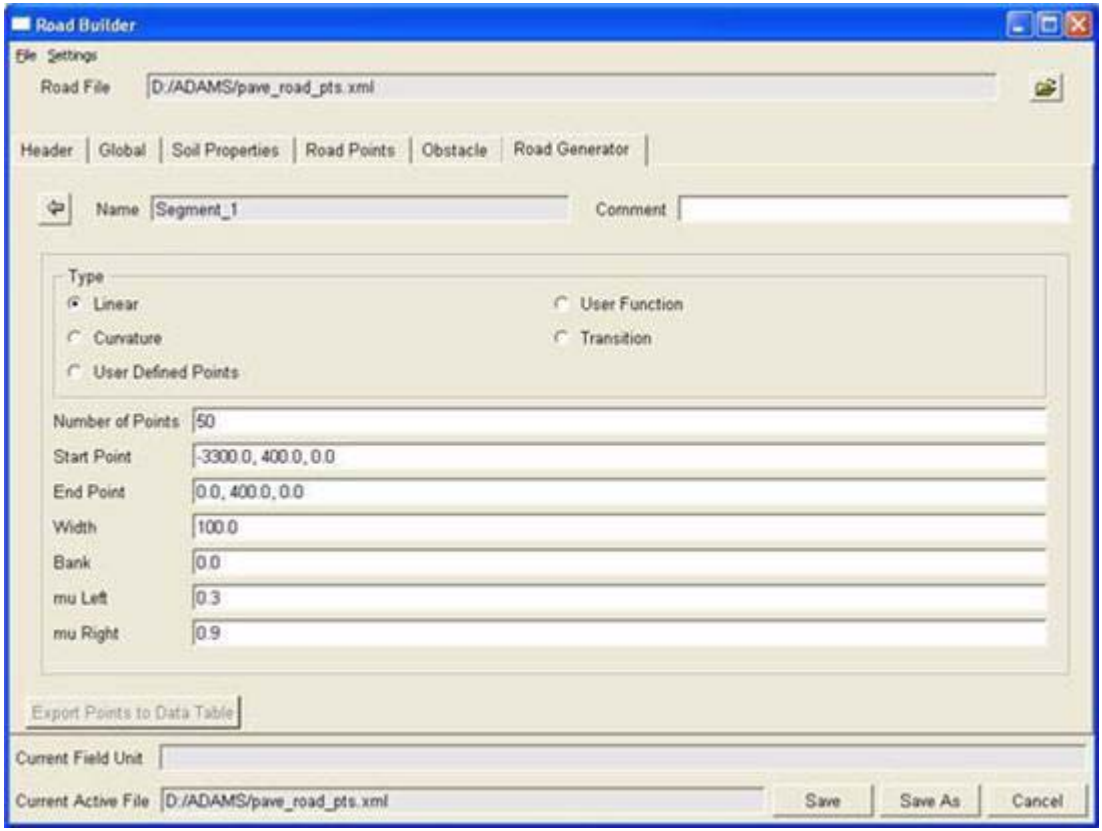
Number	X	Y	Z	Width	Bank	Friction Left	Friction Right
28	-1481.63265306	400.0	0.0	100.0	0.0	0.3	0.9
29	-1414.28571429	400.0	0.0	100.0	0.0	0.3	0.9
30	-1346.93877551	400.0	0.0	100.0	0.0	0.3	0.9
31	-1279.59183673	400.0	0.0	100.0	0.0	0.3	0.9
32	-1212.24489796	400.0	0.0	100.0	0.0	0.3	0.9
33	-1144.89795918	400.0	0.0	100.0	0.0	0.3	0.9
34	-1077.55102041	400.0	0.0	100.0	0.0	0.3	0.9
35	-1010.20408163	400.0	0.0	100.0	0.0	0.3	0.9
36	-942.857142857	400.0	0.0	100.0	0.0	0.3	0.9
37	-875.510204082	400.0	0.0	100.0	0.0	0.3	0.9
38	-808.163265306	400.0	0.0	100.0	0.0	0.3	0.9
39	-740.816326531	400.0	0.0	100.0	0.0	0.3	0.9
40	-673.469387755	400.0	0.0	100.0	0.0	0.3	0.9
41	-606.12244898	400.0	0.0	100.0	0.0	0.3	0.9
42	-538.775510204	400.0	0.0	100.0	0.0	0.3	0.9
43	-471.428571429	400.0	0.0	100.0	0.0	0.3	0.9
44	-404.081632653	400.0	0.0	100.0	0.0	0.3	0.9
45	-336.734693878	400.0	0.0	100.0	0.0	0.3	0.9
46	-269.387755102	400.0	0.0	100.0	0.0	0.3	0.9
47	-202.040816327	400.0	0.0	100.0	0.0	0.3	0.9
48	-134.693877551	400.0	0.0	100.0	0.0	0.3	0.9
49	-67.3469387755	400.0	0.0	100.0	0.0	0.3	0.9

To see the road points in 2D click button **Show X-Y Plot** & **Show X-Z Plot**. To see the road profile with shell graphics click on **Generate 3d Road**. To see in 3D, user should have Adams/Car license.

Description of Functions:

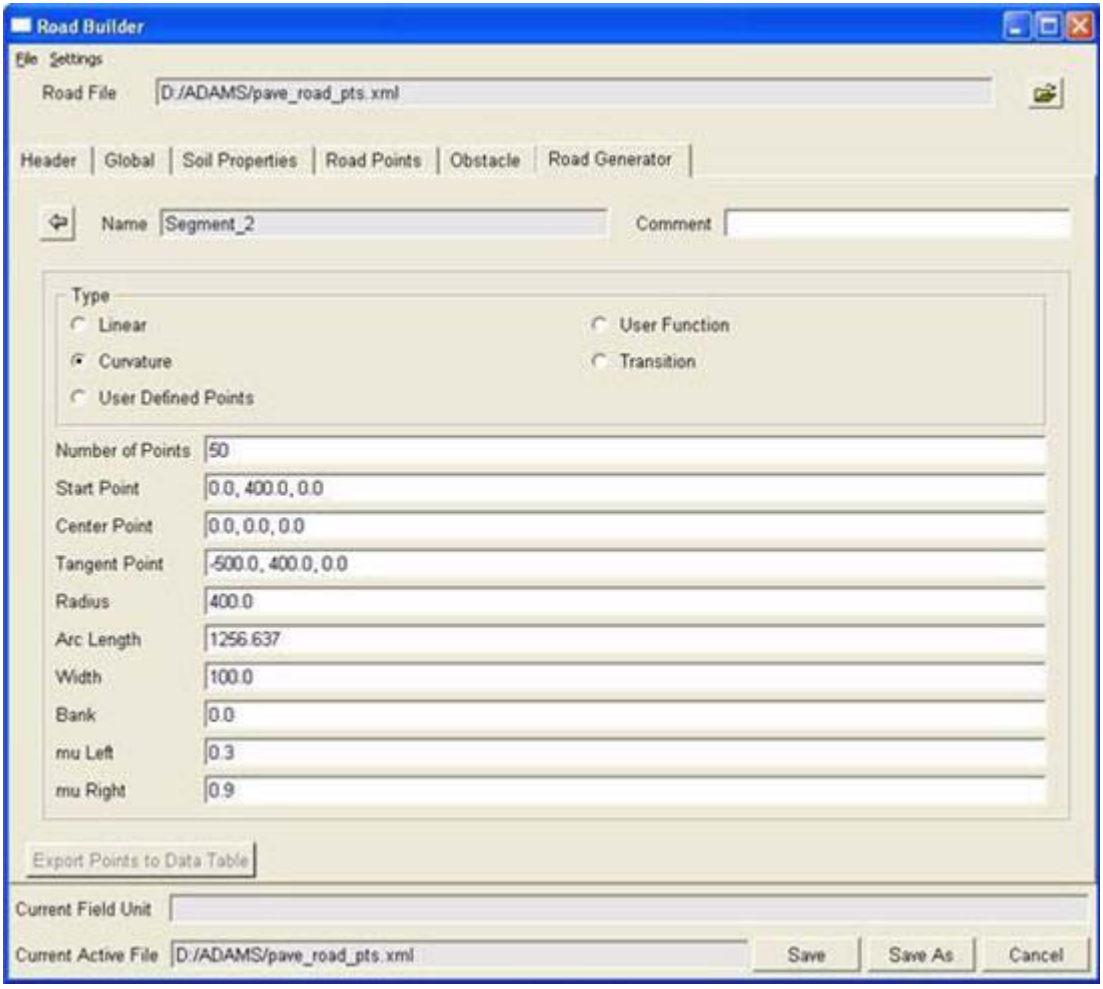
Linear:

This function will create a straight line between two given points. Inputs required are Number of points, Start point, End point, Width, Bank, mu Left and mu Right.



Curvature:

This function will create a curve. Inputs required for this function are Number of Points, Start point, Center point, Tangent Point, Radius, Arc Length, Width, Bank, mu Left and mu Right.



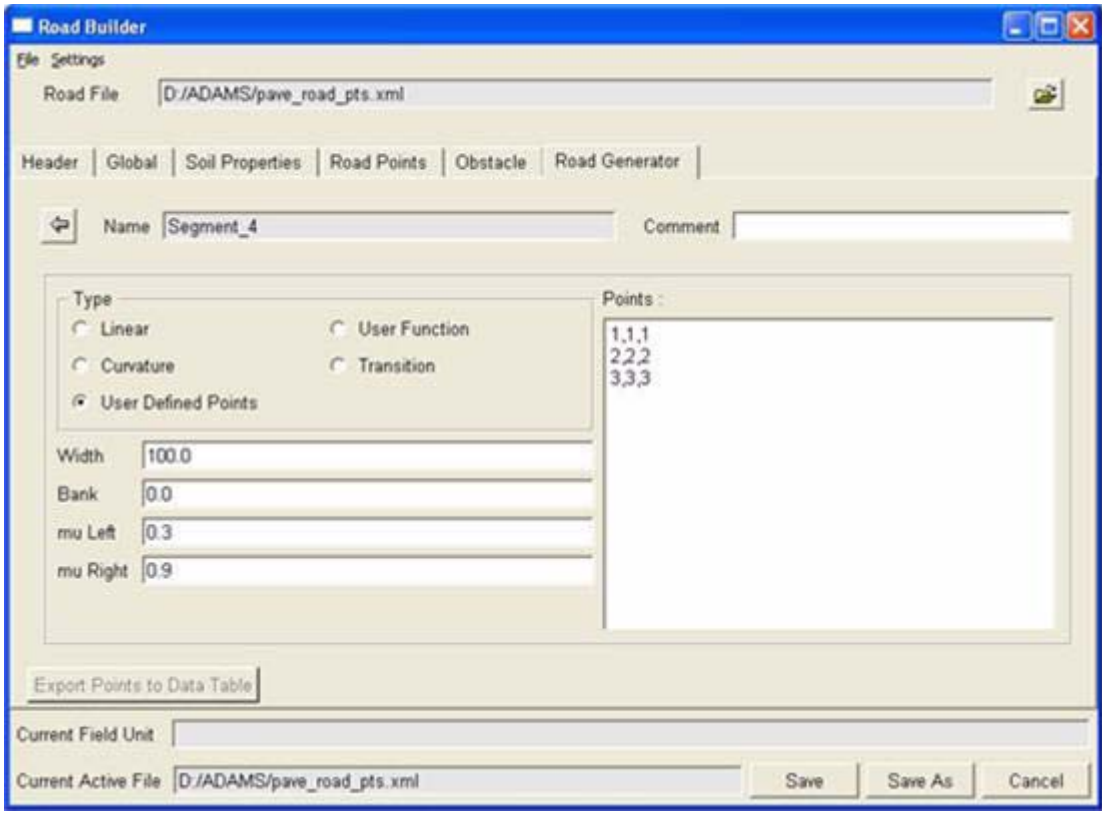
Transition:

This function will connect the start and end point of the road. Inputs required for this are segment 1, segment 1 point, segment 2, segment 2 point, Width, Bank, mu Left and mu Right.

User Defined Points:

This functionality allows the user to define their road points directly. This functionality is more useful in the case when a user wants to use the existing road point which is already in the old road data file format.

The points are appended to the road points table.



User Defined Functions:

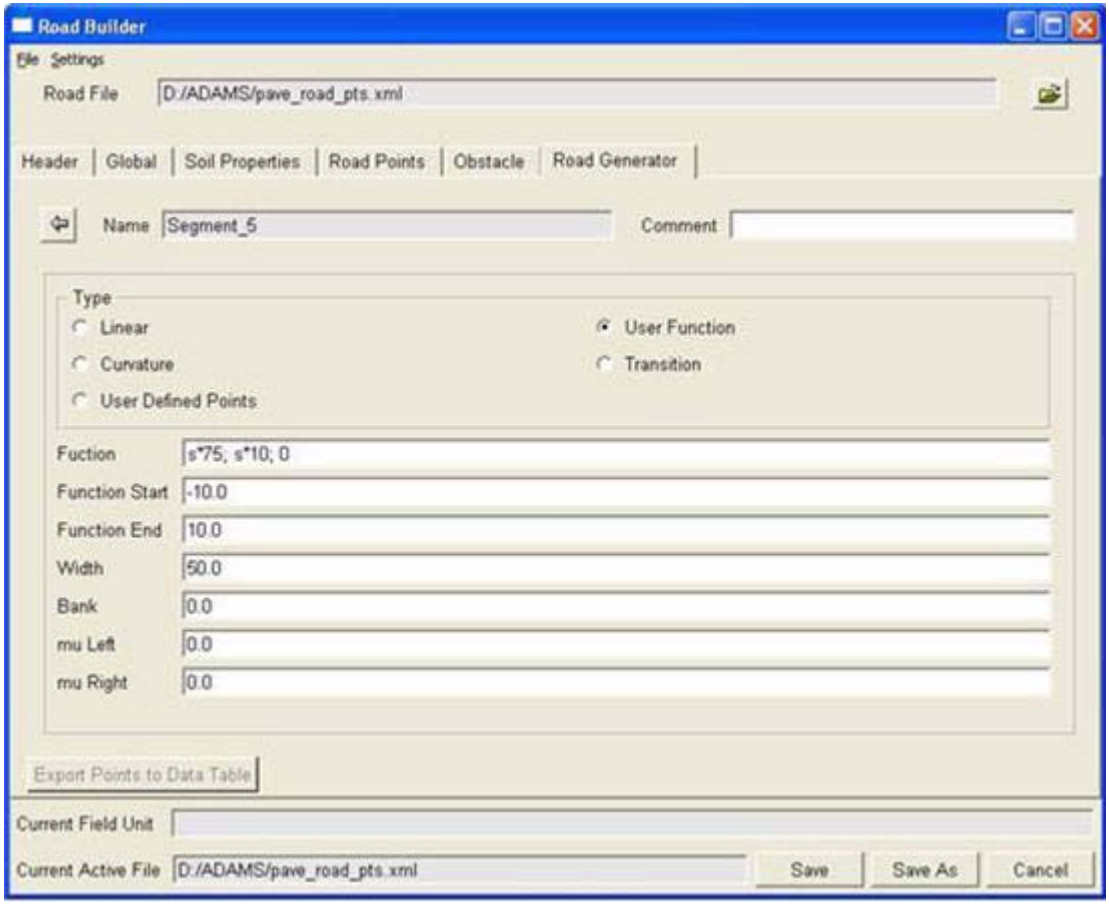
User can calculate points using their own functions.

For example:

```
User function = s*75; s*10; 0
Function Start = -10
Function End = 10
```

Calculation of Road Point:

```
-10*75; -10*10; 0
-9*75; -9*10; 0
-8*75; -8*10; 0
```


Road Builder
File Settings
Road File
D:/ADAMS/pave_road_pts.xml
Header
Global
Soil Properties
Road Points
Obstacle
Road Generator
Name
Segment_5
Comment
Type
Linear
Curvature
User Defined Points
User Function
Transition
Fuction
s*75, s*10, 0
Function Start
-10.0
Function End
10.0
Width
50.0
Bank
0.0
mu Left
0.0
mu Right
0.0
Export Points to Data Table
Current Field Unit
Current Active File
D:/ADAMS/pave_road_pts.xml
Save
Save As
Cancel

Adams/Tire 3D Shell Road Model

The 3D Shell Road utilizes a three-dimensional tire-to-road contact model that computes the volume of intersection between a road and tire. From the intersection volume the method computes an equivalent plane's effective road normal, penetration, tire to road contact point, and effective road friction. The road is modeled as a set of discrete triangular patches, the tire as a set of cylinders. This model lets you simulate a vehicle that is hitting a curb or pothole, or moving on rough, irregular road surfaces.

The 3D Shell Road uses data from both the tire property and road property files. The road model uses these blocks from the tire property file:

- Units
- Unloaded_Radius
- Width
- Shape

From the road property file it uses these blocks:

- Title
- Units
- Model
- Offset
- Nodes
- Element

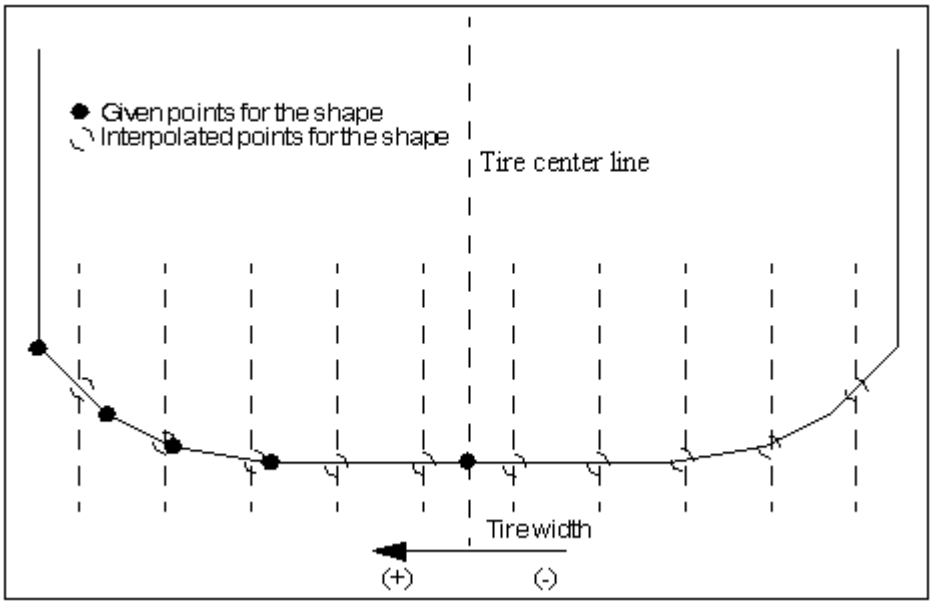
Applying the Tire Carcass Shape

This section discusses how the three-dimensional shell road applies the tire carcass shape, which is defined in the tire property file (for more information on defining shape in the tire property file, see Fiala Tire Carcass Shape). The contact algorithm interpolates the tire carcass shape to a given number of equally spaced points.

You define the tire carcass shape as a set of points in the shape table of the tire property file. Adams/Tire assumes that tire carcass shape is symmetrical over the center line of the tire. Therefore, you need to enter shape points for only half of the tire width. If the tire carcass shape is not defined, Adams/Tire defines it as a rectangular shape based on the radius and width of the tire.

You define carcass shape in terms of relative values (scales). Absolute coordinate values for the shape are computed by multiplying relative values with the unloaded radius and half-width of the tire. The relative width of the tire must be given in ascending order from 0.0 to 1.0, where the value 0.0 corresponds to the center line of the tire.

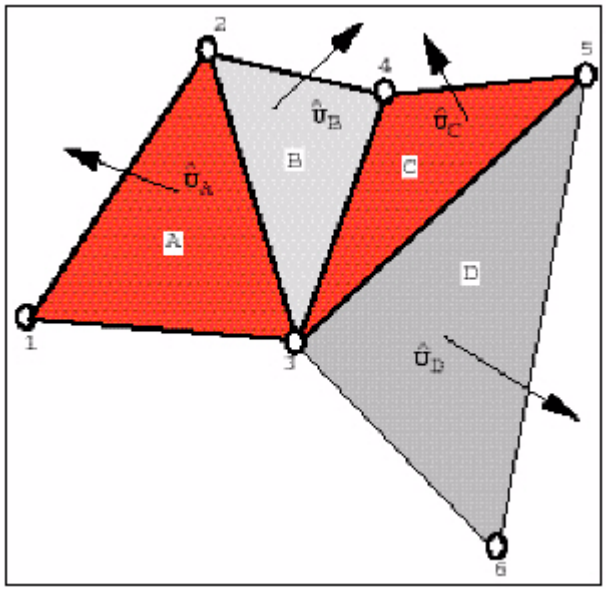
Tire Carcass Defined Using Given Shape and Interpolated Values



Road Property File

The contact algorithm works from a triangle tessellated road representation. The figure below depicts a road surface formed by six nodes numbered 1 through 6. The six nodes together form four triangular patch elements denoted as A, B, C, and D. The unit outward normal for each triangular patch is shown for the sake of clarity. Much like finite-element mesh convention, you define a road by first specifying the coordinates of each node in the road-reference-marker axis system. Subsequently, you specify the three nodes that form each triangular patch. For each triangular patch, you can specify a coefficient of friction.

Road Representation in Adams/Tire



Defining the 3D Shell Road Surface

You use a road property file to define the three-dimensional road surface. The road property file consists of five data blocks:

- Header
- Units
- Model
- Nodes
- Elements

These blocks of data can appear in any order in the file, and keywords can appear in any order within the block to which they belong.

The road property file can contain more data than what the 3D Shell Road currently requires. The 3D Shell Road searches for the blocks and keywords it needs and disregards any additional information in the file. Any line that is not recognized as input data is treated as a comment, and therefore skipped. Therefore, you can use almost any character to begin a comment line, but we recommend that you use $'s, !'s, or #'s to avoid confusion. Avoid using comment lines beginning with a square bracket ([ ), or lines that could interfere with keywords.

Tables must always appear as one set of data. No comment or empty lines are allowed between lines. Tables must always have a header line beginning with a brace, ({).

A keyword and its value are separated by an equal sign (=). You must enter strings within single (' ') or double (" ") quotes.

Examples of Blocks:

Units Block

```
Block header:          [UNITS]
Keywords:          Allowed values:
LENGTH           = {'meter', 'mm', 'cm', 'km', 'inch', 'mile'}
```

Model Block

The method keyword in the block determines the road contact algorithm Adams/Tire uses. You must set method='3D' to instruct Adams/Tire to use the 3D Shell Road algorithm.

```
Block header:          [MODEL]
Keywords:          Allowed values:
METHOD           = {'3D'}
```

Nodes Block

```
Block header: [NODES]
Keywords: Allowed values:
NUMBER_OF_NODES = <an integer number>
Tabular data:
{ node x_value y_value z_value }
1 <a real number (X)> <a real number (Y)> <a real number (Z)>
2 <a real number (X)> <a real number (Y)> <a real number (Z)>
...
<an integer number> <a real number (X)> <a real number (Y)> <a real
number (Z)>
```

Elements Block

```
Block header: [ELEMENTS]
Keywords: Allowed values:
NUMBER_OF_ELEMENTS = <an integer number>
Tabular data:
{ node_1 node_2 node_3 mu }
<an integer number> <an integer number> <an integer number> <a real
number>
<an integer number> <an integer number> <an integer number> <a real
number>
...
<an integer number> <an integer number> <an integer number> <a real
number>
```

Soft Soil Road Model

When using the Adams/Tire Soft Soil tire model, the road file needs a section that with the soil properties. All Adams/Tire road formats can be used in combination with the Soft Soil tire model as long as the road file contains a section in which these soil properties are specified. For further details see the section Using the Soft-Soil tire model.

OpenCRG Road Model

The OpenCRG Road Model (CRG = 'Curved Regular Grid') is based on the open source code delivered at http://www.opencrg.org/

The website states about the background of this road model:

'*Its objective is the provision of a series of open file formats and tools for the detailed description of road surfaces.*

The predecessor of OpenCRG® is a format called CRG which has been used internally for several years by Daimler AG. An entire suite of MATLAB® and FORTRAN tools had been developed for the handling, evaluation and generation of CRG data.

This knowledge and a whole new series of tools including a new C-API shall be made available to the broad public by means of the OpenCRG® initiative. Users shall be enabled to use all data, libraries and code samples on this website with minimum opensource licensing restrictions.'

For details about the use and format of the CRG road files is referred to the users manual available at the website. Below the use of CRG within Adams is explained.

The OpenCRG road can be used with any Adams/Tire tire model.

Positioning of the OpenCRG road

In general the position of the CRG measured road data will not match with the required position for your (vehicle model). There are two options to change the position of the road:

1. Change the position and/or orientation of the road/tire reference marker (std_tire_ref)
2. Define the x, y, z reference point in the *.crg* file, by adding the following data block (see also OpenCRG user's manual):

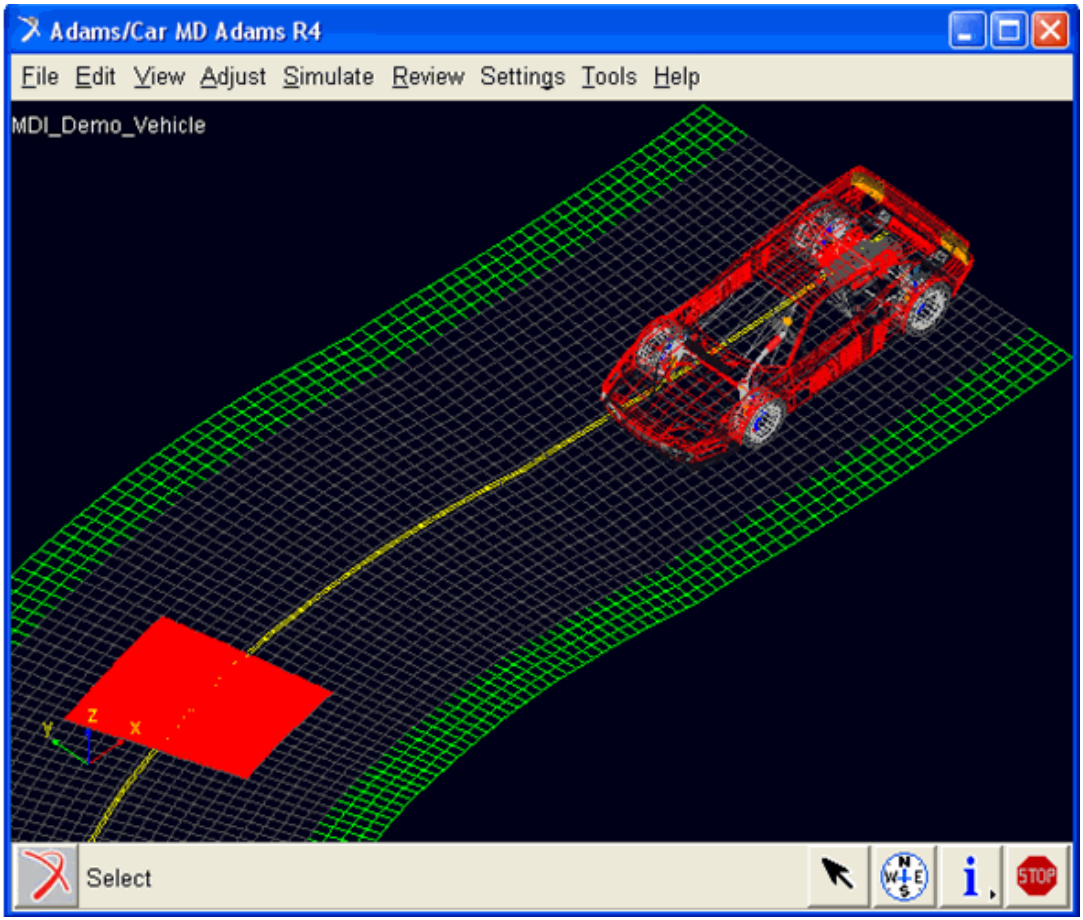
```
$ROAD_CRG_MODS
refpoint_x              = -666.0
refpoint_y              = -132.5
refpoint_z              = 29.8
refpoint_phi            = 0.0
```

Note: Some *.crg* files contain binary formatted data blocks. Adding ascii statements in such *.crg* file may easily destroy the format and make the file un-readable for the OpenCRG code. One may avoid editing the existing *.crg* file by using the $ROAD_CRG_FILE feature in a master *.crg* file. An example of a master file is the *sample_country_road_repositioned.crg* in the *acar_shared/tires.tbl* folder.

Messaging by OpenCRG

By default the messaging level is set to writing out (fatal) errors only (level 1). Changing the messaging level can be done by setting the environment variable `CRG_MESSAGE_LEVEL:`

```
CRG_MESSAGE_LEVEL   = 0   dCrgMsgLevelNone
                      1   dCrgMsgLevelFatal
                      2   dCrgMsgLevelWarn
                      3   dCrgMsgLevelNotice
                      4   dCrgMsgLevelInfo
                      5   dCrgMsgLevelDebug
```



OpenCRG road visualization

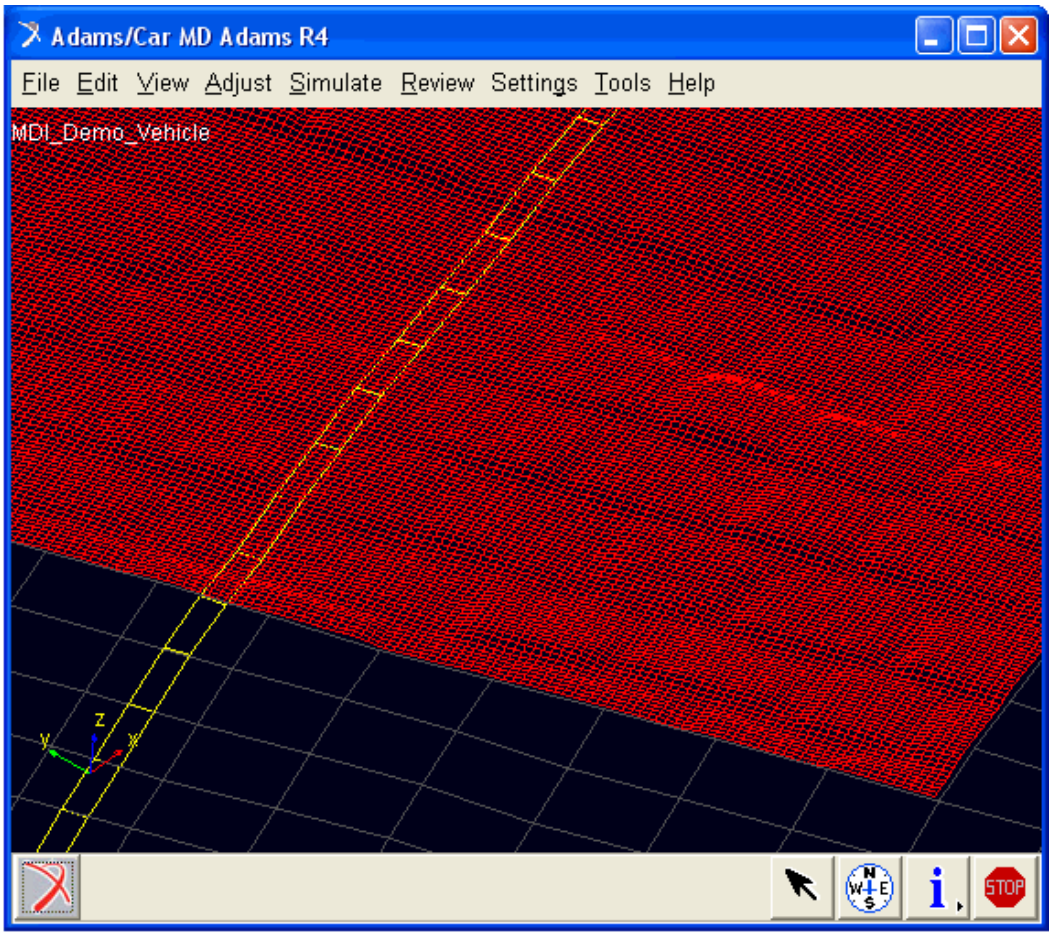
Visualization of the OpenCRG roads is supported within Adams/Car. At the end of a simulation the road grid will be visualized using default settings for grid and overall road size. The maximum number of grid datapoints used in these default settings can be changed using an environment variable `CRG_MAX_VIS_POINTS:CRG_MAX_VIS_POINTS = 10000.`

However, the user can specify his own detailed preferences for visualization by adding his specification in a `$ROAD_CRG_VISUALIZATION` data block in the *.crg* file.

```
$ROAD_CRG_VISUALIZATION
visualization_increment_u  = 0.25    !for grid size in long. direction
visualization_increment_v  = 0.25    !for grid size in lat. direction
visualization_start_u      = -10.0   !point where visualization starts
visualization_start_v      = -5.0    !point where visualization starts
visualization_end_u        = 700.0   !point where visualization ends
visualization_end_v        =  5.0    !point where visualization ends
```

Notes:

- If the `visualization_start` and `visualization_end` values exceed the measured road area the output of CRG is shown in a difference color (green).
- If the `increment` values are smaller then the measured grid value, the measured grid value is taken.
- The `$ROAD_CRG_VISUALIZATION` can also be specified in the a master *.rdg* file that is referring to another file using the `$ROAD_CRG_FILE` block.



Patches (in red) with detailed grids can be shown by adding `$ROAD_CRG_VISUALIZATION_PATCH_#` blocks within the `$ROAD_CRG_VISUALIZATION` data block, see the example below.

```
$ROAD_CRG_VISUALIZATION_PATCH_1
visualization_increment_u  = 0.014
visualization_increment_v  = 0.0132
visualization_start_u      = 20.0
visualization_start_v      = -1.0
visualization_end_u        = 22.0
visualization_end_v        =  1.0
```

The defined start, end and increment values of patches may be modified by the visualization routines to fit the patch in the global grid size of the road.

Adams/SmartDriver support

The *.crg* files can also be used for the desired path on the x-y plane in case of a '**Full-Vehicle Analysis → Course Event**' or a '**Full-Vehicle Analysis → Adams/SmartDriver**' analysis. The x and y coordinates are derived by converting the u at v = 0 coordinates towards the x, y coordinate system. Also the '**Full-Vehicle Analysis → Path Optimization**' tool can deal with the *.crg* files.

Adams/Car and Adams/Chassis quasi-statics

When quasi-statics does not converge, setting the following environment variable may help:

```
QS_USE_VARINF='YES'
```